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Spawning and recruitment of black drum, Pogonias cromis, in the lower Chesapeake Bay

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SPAWNING AND RECRUITMENT OF BLACK DRUM, *POGONIAS CROMIS*, IN THE LOWER CHESAPEAKE BAY

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SUMMARY

Black drum, Pogonias cromis, spawned in April and May of 1990 - 1991 in the area from Fisherman Island to just below Tangier Island in lower Chesapeake Bay and in Sand Shoal, Ship Shoal and Fisherman Island Inlets on the seaside coast of Virginia's eastern shore. The greatest intensity of spawning was observed in an area from Kiptopeke to Mattawoman Creek. Spawning commenced in mid- to late April when mean water column temperatures reached 9 to 10°C. Spawning activity peaked in early to mid-May when water temperatures were from 17 to 19°C and continued through May. When present, abundances of eggs ranged from 0.1 to 37.9 eggs m^{-2} in 1990 and from 0.1 to 30.0 eggs m^{-2} in 1991. Mean abundance of eggs in any stratum ranged from 0.1-16.0 eggs m^{-2} in 1990 and 0.1-9.6 eggs m^{-2} in 1991.

Estimates of the daily production of eggs and total spawning biomass calculated using three areal estimate methods during the two-year survey ranged from 3.5 - 4.6 x 10^8 eggs/day and 50,630-161,764 pounds (23,013-73,529 kg). Ninety-five percent confidence limits and coefficients of variation in 1990 were 2.21 x 0^9; 45%, and in 1991 were 8.20 x 10^8; 20%.

There are no published records of larvae of black drum being collected in the Chesapeake Bay. During spring sampling in 1990 and 1991, collections yielded only 16 specimens ranging in size from 2.2 to 5.1 mm total length. Densities of larvae of black drum were low, 1.1-2.0 larvae m^{-3}. Thus, our results confirm that hatching of eggs and survival of larvae to feeding stages does occur naturally in the Chesapeake Bay.

Results of two 24-h time-series experiments conducted in 1990 and 1991 indicated that black drum spawned in early morning between 2400 and 0800 h. Examination of egg cohort decline over the period of sampling revealed mortality rates of 60-72% per day. These values corresponded closely to other studies of fish egg mortality and mirror the results of Cowan et al. (1991) who calculated egg mortality of black drum in mesocosms off Cape Charles harbor in 1990.

Laborious and extensive sampling of potential and historic nursery habitats yielded few

(n=13) juvenile specimens of black drum. Frisbie (1961) commented on the rarity of juvenile black drum from the paucity of documented historical records of juveniles within Chesapeake Bay. Our sparse data confirmed Frisbie's (1991) hypothesis that juvenile black drum are uncommon in Chesapeake Bay and suggested that black drum spawning in 1990 and 1991 was characterized by little or no survival.

ACKNOWLEDGEMENTS

Many people contributed to the successful completion of this project. We thank J. McGovern, M. Cavalluzzi, J. Field, C. Baldwin, D. Gouge and K. Kavanagh for their help in both the juvenile habitat and egg production portions of this work. T. Shannon, S. Alexander, J. Posenau and W. Mathews were important in the development and maintenance of the hydrographic equipment and the camera-net system. L. Durand Ward, the crew of the R/V Bay Eagle, C. Machen and the crew of the R/V Langley made this work possible with their professionalism and abilities in vessel handling. Finally, special thanks to Patricia Crewe who spent many hours in the field and in the laboratory collecting and sorting samples.

INTRODUCTION

Black drum, Pogonias cromis, is the largest of the western Atlantic sciaenids and occurs from Argentina to the Gulf of Maine (Hildebrand and Schroeder, 1928; Bleakney, 1963; Silverman, 1979). In Virginia, a large population of adults seasonally migrates along the seaside coast and into the Chesapeake Bay. This stock is subject to intense commercial and recreational fishing pressure partially due to the predictability of their arrival. Efforts have been made to compile catch rates, sex ratios, size composition and gonad condition (Desfosse, 1986; Jones and Chittenden, in progress). Presently, the black drum fishery is regulated only by a minimum size limit that protects fish less than 16 inches TL. Larger fish are unprotected with the exception of a two fish-per-person, self-imposed limit on charter boats, however, new regulations have been proposed (J. Travelstead, pers. comm.).

Black drum spawn from November to June at sea near the mouths of inlets and in large bays from Delaware to Texas (Simmons and Breuer, 1962; Joseph et al. 1964; Holt et al. 1985; Murphy and Taylor 1989; Peters and McMichael 1990). Thomas and Smith (1971) reported that spawning occurred from early April to June and peaked around mid-May in Delaware Bay. The spawning season is more protracted further south. Peters and McMichael (1990) collected larvae from January to mid-May in Tampa Bay, Florida, and larvae were collected from January to April in the northwestern Gulf of Mexico (Cowan and Shaw, in press). A possible secondary spawning period reportedly occurs from late July to November among younger age classes off Texas (Pearson, 1929). Batch fecundity estimates are unavailable for northern stocks but range from 1.43×10^3 (range = 0.51 to 3.39×10^6) (Nieland and Parker, 1990; D. Nieland, pers.comm.) to 6.0×10^6 (Pearson, 1929) eggs per female in the Gulf of Mexico. Pearson (1929) examined only one specimen (100 cm TL; no weight reported) while Nieland and Parker (D. Nieland, pers.comm) surveyed only small fish (< 945 mm FL; 13.15 kg).

Female black drum that enter Chesapeake Bay in the early spring usually are large

(15 - 40 kg) and gravid. Richards (1973) examined ovaries of fish collected in Chesapeake Bay and suggested that spawning began in April when Bay water temperatures reached 15°C then proceeded until June. During these months, 55,046 (1989) and 52,117 (1990) pounds of black drum were landed by commercial gear (pound nets and gill nets) in Virginia (pers.comm., David Boyd, Virginia Marine Resources Commission (VMRC)). Recent landings may be compared to a 40-year high of 414,000 pounds in 1954 and a low of 7,000 pounds in 1975 (VMRC annual fishery landings report). These data suggest that the spring fishery in Virginia is directed towards a spawning stock. However, few direct observations of spawning activity exist in the form of plankton collections of pelagic eggs.

Black drum eggs are pelagic, range in size from 0.8 to 1.0 mm and possess multiple oil globules in early stages that coalesce to a single globule just prior to hatching (Joseph et al., 1964; Lippson and Moran, 1974). This morphological description is based on a single published record of black drum eggs collected in the lower Chesapeake Bay near Cape Charles, Va. (Joseph et al., 1964). In a recent unpublished study (Cowan et al., 1991), black drum eggs were also collected off Cape Charles City, Va. Extensive ichthyoplankton surveys in the Bay have not detected black drum eggs (Pearson, 1941; Olney, 1983; Olney and Boehlert, 1987). Pearson (1941), did not identify pelagic eggs whereas Olney (1983) and Olney and Boehlert (1987) could not distinguish between species of sciaenid eggs in their samples, because several sciaenids (ie.- <u>Bairdiella</u> <u>chrysoura</u>, <u>Cynoscion</u> <u>nebulosus</u>, <u>C</u>. <u>regalis</u> and at least two species of <u>Menticirrhus</u>) in the mid-Atlantic are spring spawners and many of their egg diameter and oil globule numbers overlap (Johnson, 1978; Olney, 1983). This identification problem is not intractable, however, since field caught eggs can be raised to hatching for a positive identification (Joseph et al., 1964; Holt et al., 1985).

Larval black drum have been described (Ditty, 1990) and collected in Delaware Bay (Thomas and Smith, 1971) and from South Carolina (McGovern and Wenner, 1990) to the Gulf of Mexico (Pearson, 1929; Jannke, 1971; Price and Schleuter, 1985; Peters and McMichael, 1990; Cowan and Shaw, in press). Thomas and Smith (1971) collected only two specimens (<10 mm TL) in a low salinity (<4.0 ppt) tributary of Delaware Bay. Other collections were made in bays and passes with plankton gear and in shallow, quiet tidal creeks, secondary bays and lagoons with seines and trawls. King (1971) collected larvae at both surface and mid-water plankton stations, finding no diel variation in abundance. Peters and McMichael (1990) collected the majority of their specimens in mid-water at night in lower Tampa Bay. The nursery habitats of late larval black drum are shallow tidal creeks and sloughs with nutrient rich, muddy bottoms (Peters and McMichael, 1990).

Black drum larvae have not been collected in the pelagic environment of Chesapeake Bay (Joseph et al., 1964; Olney, 1983; Olney and Boehlert, 1987). Numerous surveys (Richards and Castagna, 1973; Orth and Heck, 1980; Cowan and Birdsong, 1985) of a variety of potential nursery habitats have also failed to collect late larval stages of black drum. Thus, the extent to which inefficient sampling or high mortality during egg and larval stages account for the scarcity of larval black drum is unknown.

Juvenile black drum are uncommon in Chesapeake Bay (Hildebrand and Schroeder, 1928; Frisbie, 1961; Richards and Castagna, 1973). The few fish (n = 350; size range = 22 - 200 mm in length) collected during the 63-year period encompassed by these reports were found in a variety of habitats including shallow, muddy, nutrient rich tidal creeks and high salinity sloughs and embayments. Although distributional patterns are similar to those described in the Gulf of Mexico (Silverman, 1979; Peters and McMichael, 1990), juvenile abundance in Chesapeake Bay is low compared with more southern waters (Frisbie, 1961; Simmons and Breuer, 1962: Joseph et al., 1964; Peters and McMichael, 1990). Frisbie (1961) noted that Chesapeake Bay lies near the northern geographic limit of the reproductive range of black drum and suggested that environmental conditions, particularly low temperatures, may severely limit larval and juvenile survival. Frisbie's hypothesis (1961) suggest that reproductive success of this northern stock is consistently low.

OBJECTIVES

The overall goals of this research were to contribute to the understanding of the reproductive ecology of black drum in Chesapeake Bay. The planned research included three primary objectives: 1) to document spatio-temporal variability of eggs and larvae and estimate seasonal egg production and spawner biomass; 2) to determine time of spawning and estimate mortality of eggs by Lagrangian time-series studies on the spawning grounds; and, 3) to utilize various sampling strategies in an attempt to define juvenile nursery habitat of black drum juveniles.

JOB 1

Spatio-temporal variability of eggs and larvae, egg production and female biomass estimation of black drum, Pogonias cromis, in lower Chesapeake Bay

METHODS

Field Survey. - Weekly ichthyoplankton cruises (n = 8, 1990; n = 9,1991) were conducted during the period 9 April to 1 June in 1990 and 1 April to 30 May in 1991. Stations were randomly chosen before each cruise from a 364-station grid that was divided into 4 strata (4 stations each) encompassing an area from Fisherman Island at the northern base of the Chesapeake Bay Bridge Tunnel to just below Tangier Island (Figure 1). In addition to stations in the lower Chesapeake Bay, three fixed stations were occupied occasionally during 1990 on the seaside of the eastern shore off Fisherman Island, Ship Shoal Inlet and Sand Shoal Inlet. Samples were obtained with an in situ silhouette photography system consisting of paired 335 µ-mesh nets fitted to a rigid frame (Figure 2, Olney and Houde, in press). The frame supports a Benthos Model 373 camera, hydrographic sensors and flowmeters. As plankton passed through an open chamber in the camera, photographs were taken at 1-s intervals and temperature, conductivity and depth recorded for each frame. The paired net yielded a replicate preserved plankton sample. All deployments of the camera system were 5-min, stepped oblique tows.

Egg Identification. - Only preserved collections from 1990 and 1991 were processed in the laboratory and all eggs of sciaenids were removed for identification and enumeration. Sciaenid eggs were identified by size (0.65- 1.10 mm outside diameter) as well as the presence and number of oil globules. Species of sciaenids that reportedly spawn in the lower Chesapeake Bay during spring include; black drum, Pogonias cromis; weakfish, Cynoscion regalis; spotted seatrout, Cynoscion nebulosus; silver perch, Bairdiella chrysoura and kingfishes, Menticirrhus sp. In early stages, eggs of kingfishes possess multiple (>5) oil globules (Johnson, 1978). Eggs

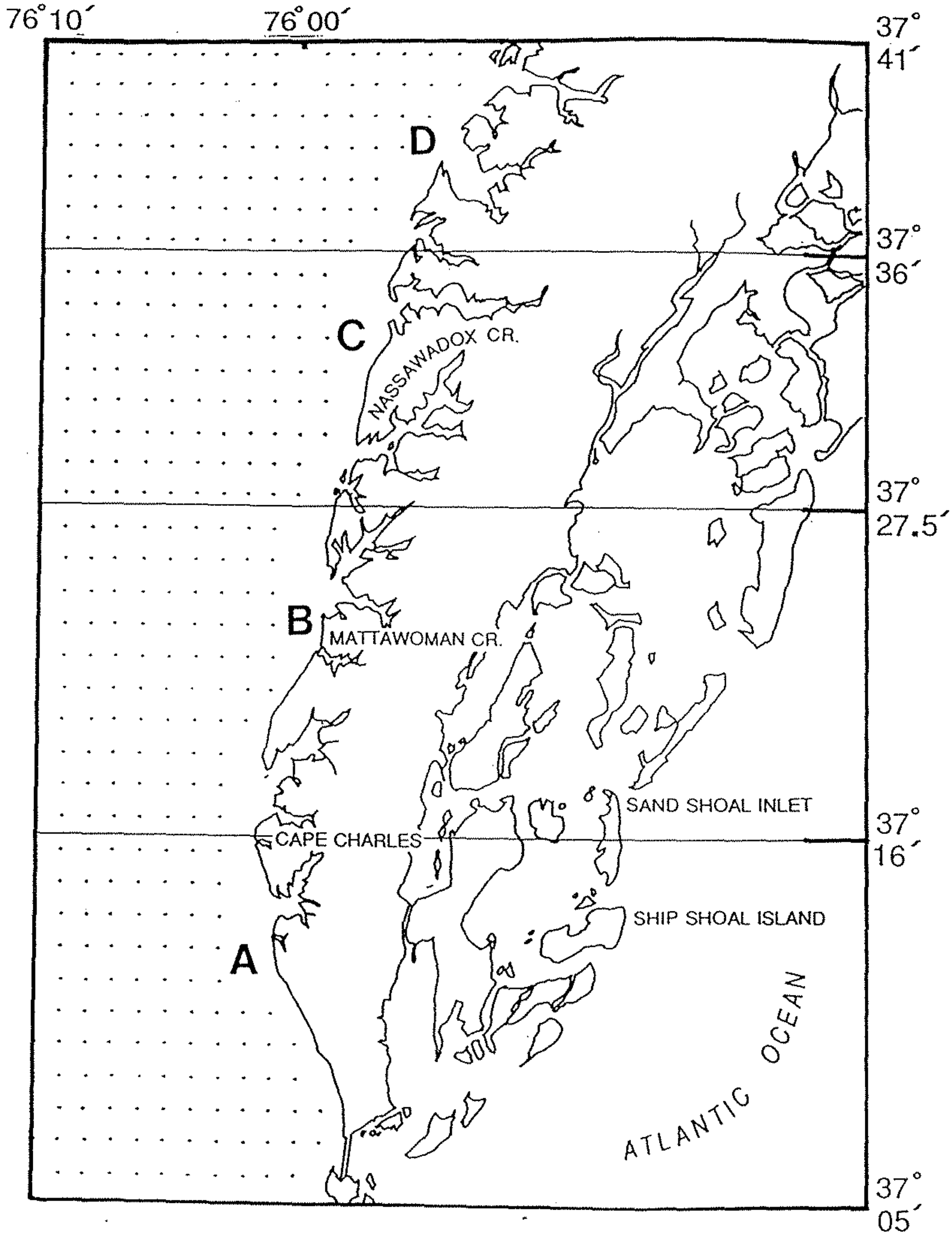

Figure 1. Ichthyoplankton survey grid.

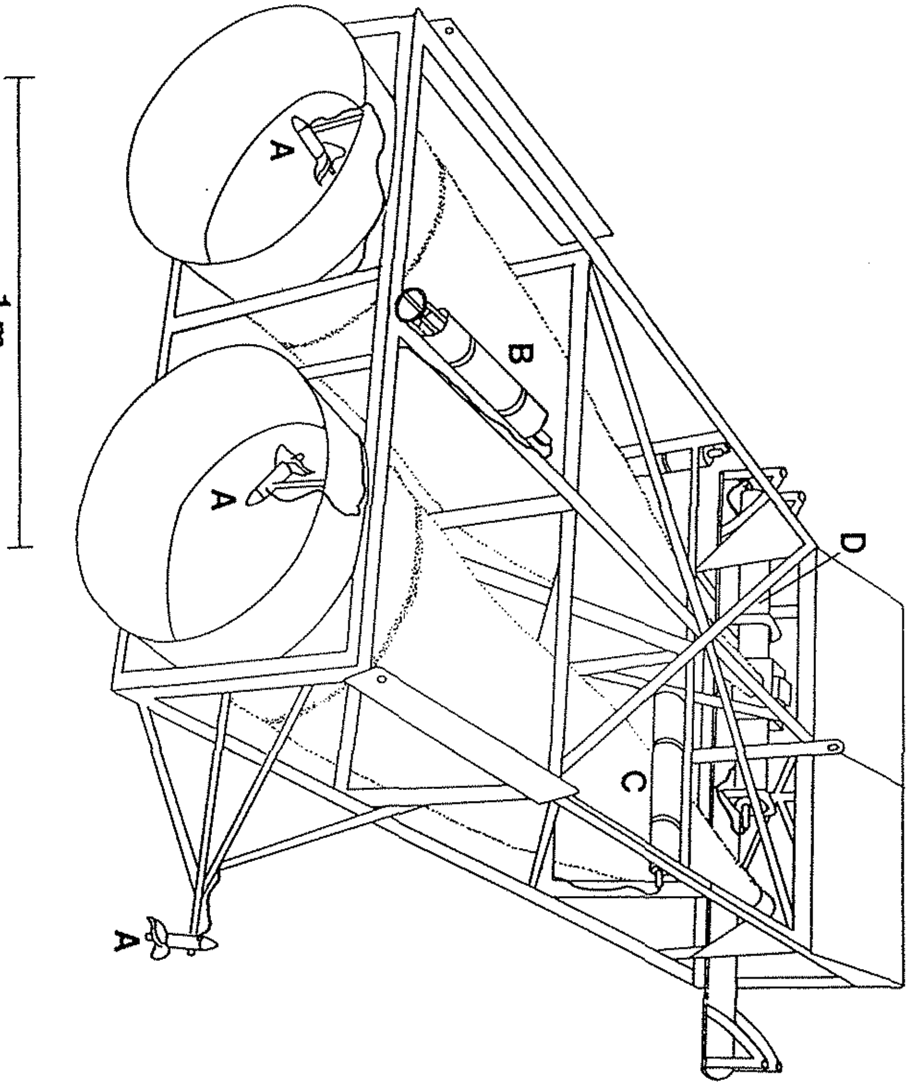

Figure 2. Schematic of plankton camera sampler. Paired nets are 60 cm in diameter and constructed of 335 micron mesh Nitex.

of spotted seatrout are similar in size to those of silver perch and weakfish and may be confused with these forms. In our samples, individual eggs were measured to the nearest .05 mm in order to construct histograms of egg diameter distributions. These distributions were compared to previously published reports for identification. Hatching experiments and examination of egg diameters from unovulated oocytes in weakfish, Cynoscion regalis, were also important in the identification process. Larval sciaenids were removed from preserved samples and identified to the lowest possible taxonomic level. The presence of first feeding larvae that can be identified to species are important in corroborating egg identifications.

Estimates of egg density resulting from each survey were used in an egg production model modified from Houde (1977) and Olney et al. (1991) to estimate spawning stock size. The model incorporates estimates of size-specific fecundity, sex ratio and egg mortality to yield an estimate of the total biomass required to produce the observed annual egg production. Table 1 lists and defines all of the variables used in the following calculations.

Raw counts of eggs of black drum from preserved samples were standardized to individuals per m^2 for each deployment using the expression:

$$(1): E_t = \frac{N}{A}$$

where: E_t = number of eggs over one m^2 of sea surface

N = number of eggs in a preserved sample

A = area sampled (m^2), calculated by dividing the volume filtered (m^3) by maximum gear depth (m).

Egg density (E_t) was adjusted by an instantaneous rate of daily mortality (z), determined from a time-series mortality study (see Job 2), following Olney et al. (1990). The magnitude of adjustment was dependent upon the sampling times proximity to the average time of occurrence, in preserved samples, of newly fertilized eggs (see Job 2). Equation 2 was used to determine the initial abundance (E_o) of eggs at the time of spawning.

Table 1. Definitions of variables used in egg production and variance estimates.

A = area sampled (m^2), calculated by dividing the volume filtered (m^3) by maximum gear depth (m)

A_i = area of a single station (3.43×10^6 m^2)

D = number of days represented by each cruise

d_i = egg stage duration (36 hours for black drum)

E^o = initial abundance of eggs in any single sample

E_t = egg abundance at time t over 1-m of sea surface

k_i = number of stations in a specific polygon or contour

k_j = the number of stations in any particular cruise

n = the number of stations in a high/low production area

N = the number of eggs in a preserved sample

P_s = the number of eggs spawned over a cruise period

P_t = individual cruise estimate of egg production

P_I = egg production estimate from Method I

P_{II} = egg production estimate from Method II

P_{III} = egg production estimate from Method III

r = the number of cruises used to estimate total egg production

R = average egg density in an area (high/low production)

s_i^2 = variance estimate for the number of eggs present under 1 m^2 of sea surface for cruise i

S_p^2 = cruise specific variance estimate

$S_{p.}^2$ = variance estimate on the number of eggs spawned annually

t = time of collection (fraction of 1-d since spawning

z = mortality coefficient

$$(2) \quad : \quad E_o = \frac{E_t}{e^{-zt}}$$

where: E_o = initial abundance of eggs

E_t = egg abundance at time t

z = mortality coefficient

t = time of collection (fraction of 1 d since the actual time of spawning.

The number of eggs and larvae per m^2 of sea surface (E_o) was used to construct density polygons or contours to assess spawning area for each cruise following three methods. The area of regions with only one positive station was equal to the area of a single station (3.43×10^6 m^2). Polygons were constructed in regions with at least two positive stations (stations where black drum eggs were collected) by first connecting the two stations with a line and then drawing lines perpendicular to the closest stratum boundary. Areas where densities exceeded 2 eggs/m^2 were considered high intensity spawning regions and those with densities less than 2 eggs/m^2 were low intensity. Three different methods of determining spawning area were utilized. Polygons in Method I were constructed by connecting positive stations of similar density in such a way as to keep the area of the polygon at a minimum (Figure 3). In Method II, non-overlapping polygons with similar densities were constructed with no regard to size (Figure 4). Finally, in Method III, a contour was constructed to incorporate all positive stations with no regard to egg density. To calculate total area in Method III, it was assumed that spawning occurred inshore of the contour. Method III consistently resulted in the greatest areal estimate (Figure 5). Average estimates of polygon specific egg density (R) were calculated using equation 3, for areas of high (> 2.0 eggs/m^2) and low spawning intensity (< 2.0 eggs/m^2).

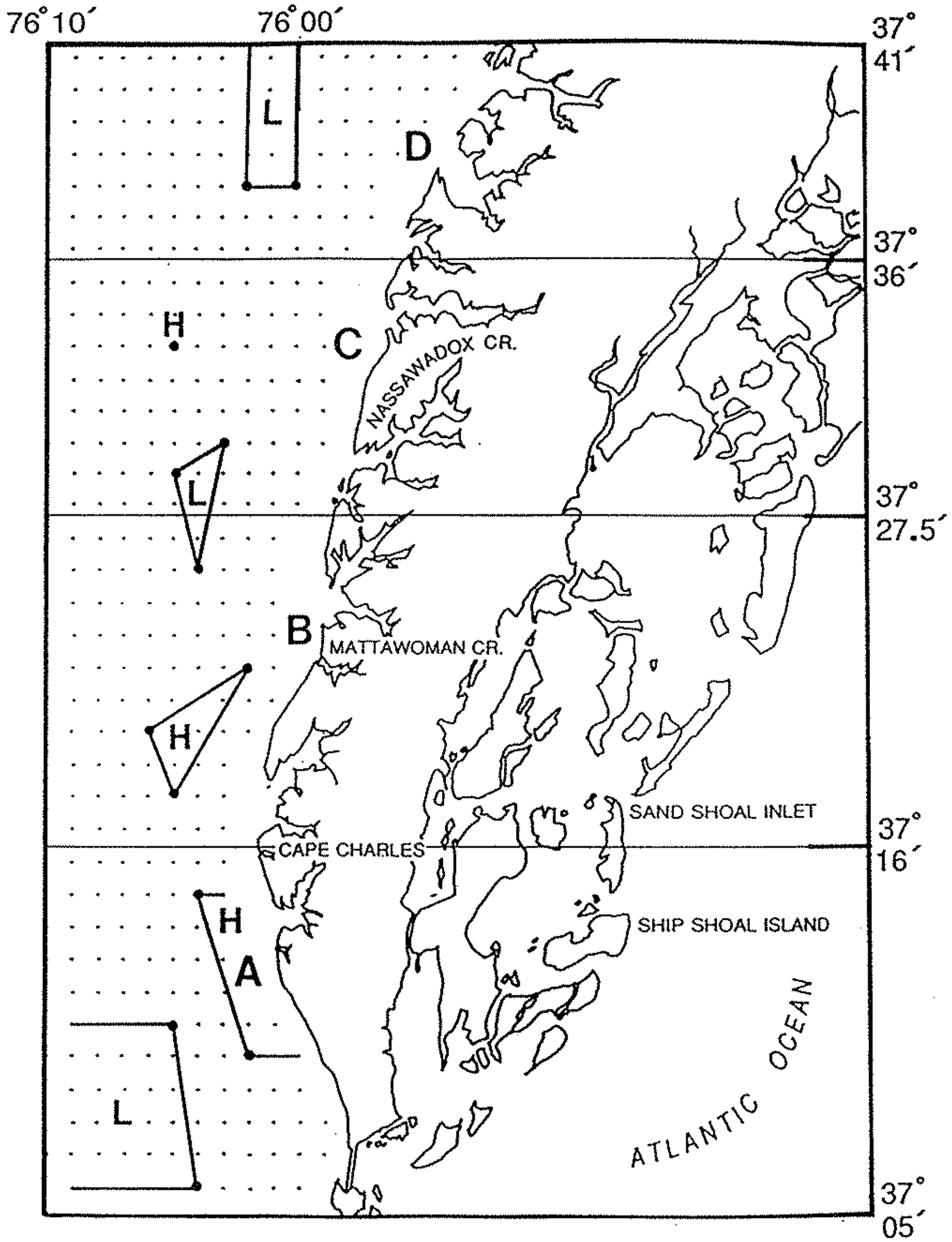

Figure 3. Example of polygons constructed using Method I. H = areas of high spawning intensity, L = areas of low spawning intesity. (BD91-06)

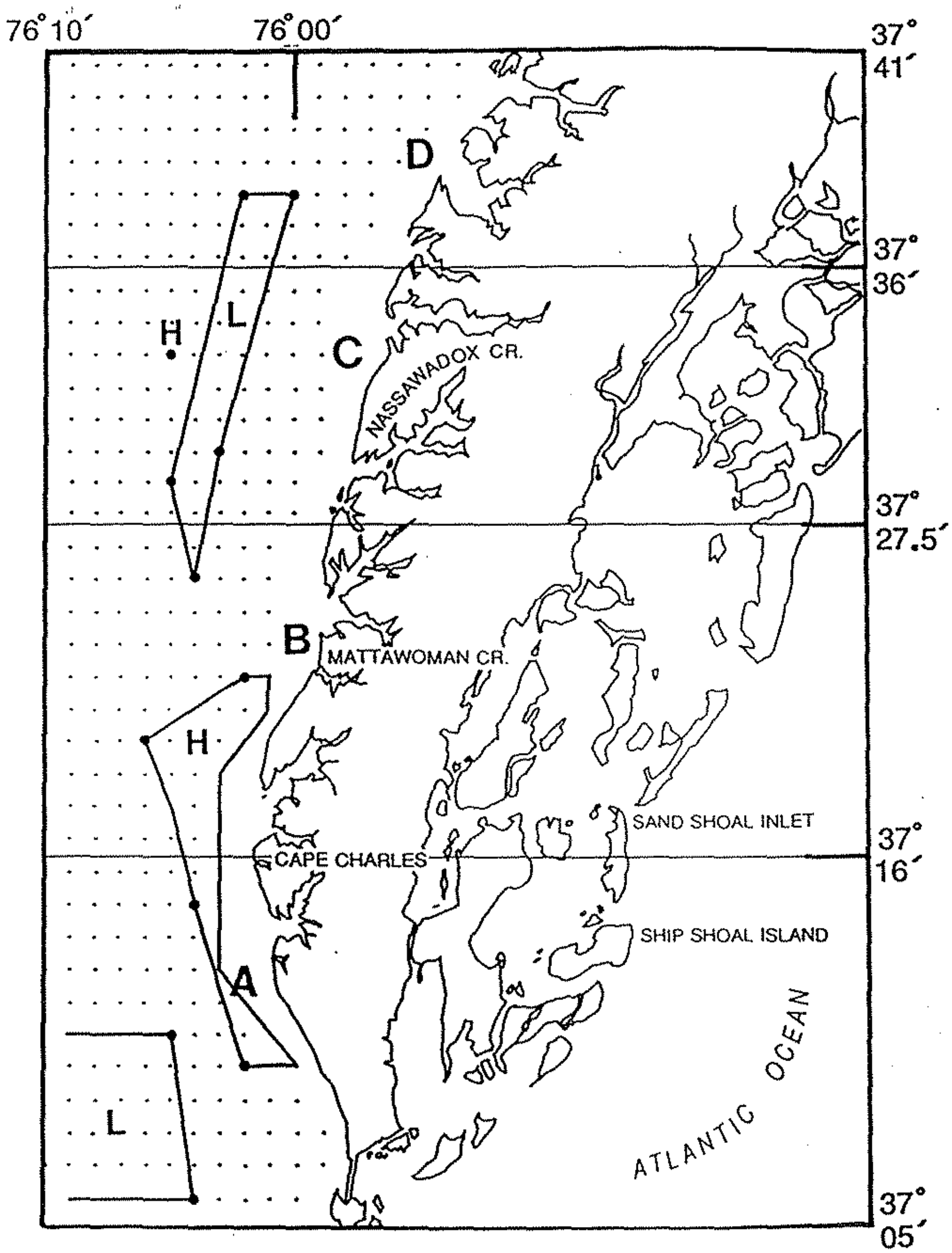

Figure 4. Example of polygons constructed using Method II. H = areas of high spawning intensity, L = areas of low spawning intensity. (BD91-06)

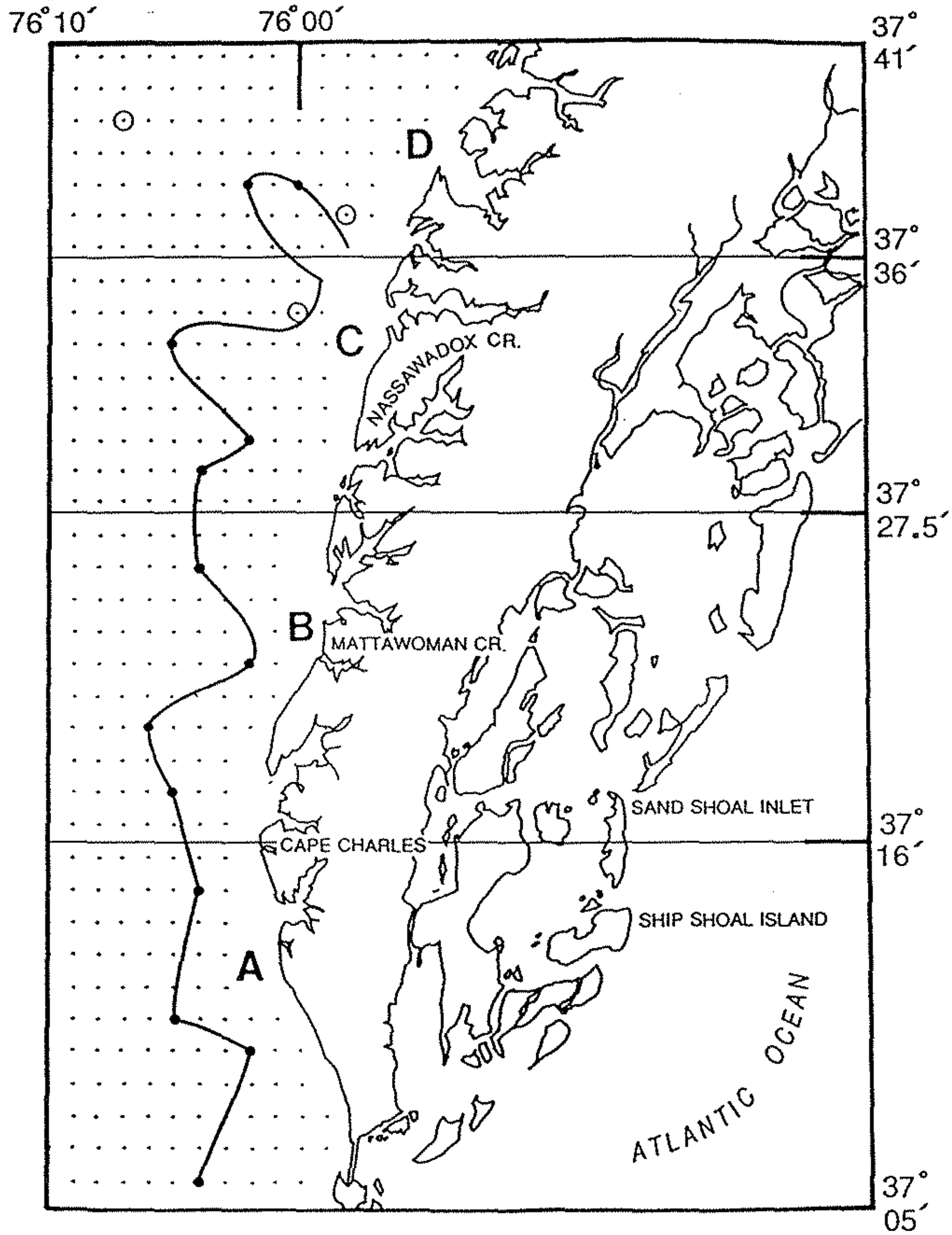

Figure 5. Example of contour, Method III, assessment of spawning area. (BD91-06)

$$(3) \quad : \quad R = \sum_i \frac{E_o}{n}$$

where: E_o = egg density at a single station.

n = number of stations sampled in high\low production area.

The estimate for the total number of eggs within polygons (P_I, P_{II}) or contours (P_{III}) was determined by equation 4:

$$(4) \quad : \quad P_{(I,II,III)} = R(k_i)(A_i)$$

where: R = average egg density in an area (either high or low density.

k_i = number of stations in an area

A_i = area of a station (3.43×10^6 m^2)

The sum of all low and high production areas yield an estimate of total production (P_t) for a single cruise. The number of days (D) represented by each cruise was defined as the days included in the cruise plus half the days since the prior cruise and half of the days until the next (Sette and Ahlstrom 1948). The estimate of the number of eggs spawned over a cruise period (P_s) is derived from equation 5:

$$(5) \quad : \quad P_s = \frac{P_t D}{d_i}$$

where: P_t = individual cruise estimate of egg production.

D = number of days represented by each cruise.

d_i = egg stage duration (36 hours for black drum).

The sum of all cruise estimates provided an estimate of total, seasonal egg production for black drum.

Estimates of female biomass required to produce the observed number of eggs were obtained by dividing the seasonal egg production by fecundity (eggs per kilogram). During

1990-1991, black drum displayed a 1:1 sex ratio (Jones and Chittenden, in progress); therefore, estimates of population biomass were determined by doubling the female biomass estimate.

Variance estimates for each cruise and the total seasonal egg production estimate were calculated using the method of Taft (1960) as used in Houde (1977). The general equation for cruise specific variance was:

$$(6)\quad : \quad S_p^2 = D^2 \sum_{j=1}^{k_j} \frac{A_i^2 \; s_i^2}{d_i^2}$$

Where: S_p^2 = cruise variance estimate

D = the number of days represented by cruise i

A_i = the area (m^2) represented by the j^{th} station in the i^{th} cruise

d_i = egg incubation time (days)

s_i^2 = the variance estimate for the number of eggs present under 1 m^2 of sea surface for cruise i

k_j = the number of stations in cruise i.

Cruise specific variance estimates are used to calculate variance for total seasonal egg production by:

$$(6)\quad : \quad S_{p.}^{2} = \sum_{i=1}^{r} S_p^2,$$

Where: $S_{p.}^2$ = variance estimate on the number of eggs spawned annually

r = the number of cruises upon which the estimate of annual spawning is based.

S_p^2 = defined in equation 5.

Confidence intervals (95% C.I.) for the number of eggs produced during the spawning season were calculated using equation 8. Variables used are defined above.

$$(8)\ :\ CI\ (95\%) = \pm 1.96\sqrt{\frac{S_{p\cdot 2}}{k_j}}$$

RESULTS

During eight cruises in April and May 1990, 128 stations representing 107 locations were sampled (some stations were sampled more than once, Figure 6). Weekly cruise tracks are depicted in Figures 7 - 14. During 9 cruises in 1991, 123 stations were occupied for a total of 144 collections (Figure 15). Weekly cruise tracks are depicted in Figures 16 - 24.

Eggs from samples in 1990 (n = 4,863) were measured and a histogram of egg diameters was constructed (Figure 25). Sciaenid eggs less than 0.83 mm (outside diameter) were designated as silver perch based on previously published data as well as shipboard and laboratory hatching experiments. In these trials, live sciaenid eggs were grouped by size and then incubated until hatching. Yolksac larvae were fed Artemia nauplii and raised to an identifiable size. These larvae were then used to validate egg identifications. Preserved material resulting from rearing trials are deposited in the VIMS larval fish reference collection. Eggs that ranged in size from 0.83 to 0.95 mm (outside diameter) were identified as weakfish based on previous studies and the hatching experiments. Additionally, numerous yolked, unovulated weakfish oocytes were measured (S. Barbieri, pers. comm.) and their diameters mirrored those reported here. The largest sciaenid eggs in collections (0.95 to 1.1 mm outside diameter) were identified as black drum based on previous data and hatching experiments. Eggs of black drum removed from samples in 1991 (n = 1,180) were identified based on the size distributions determined in 1990 (Figure 26). Table 2 summarizes the 1990 and 1991 sampling effort and the number of eggs of black drum collected during each cruise.

Spawning of black drum was not observed until the 22nd or 23rd of April in each year. Samples collected during weekly cruises conducted prior to these dates contained no black drum eggs. Since eggs were present on the last cruise of each year, we were unable to document the time of cessation of spawning. In each year, peak spawning (cruises with mean egg abundance >4 eggs m^{-2}) was observed between 1 May and 15 May when average water column temperature ranged from 16-19.°C. Altogether, 2,294 eggs of black drum were

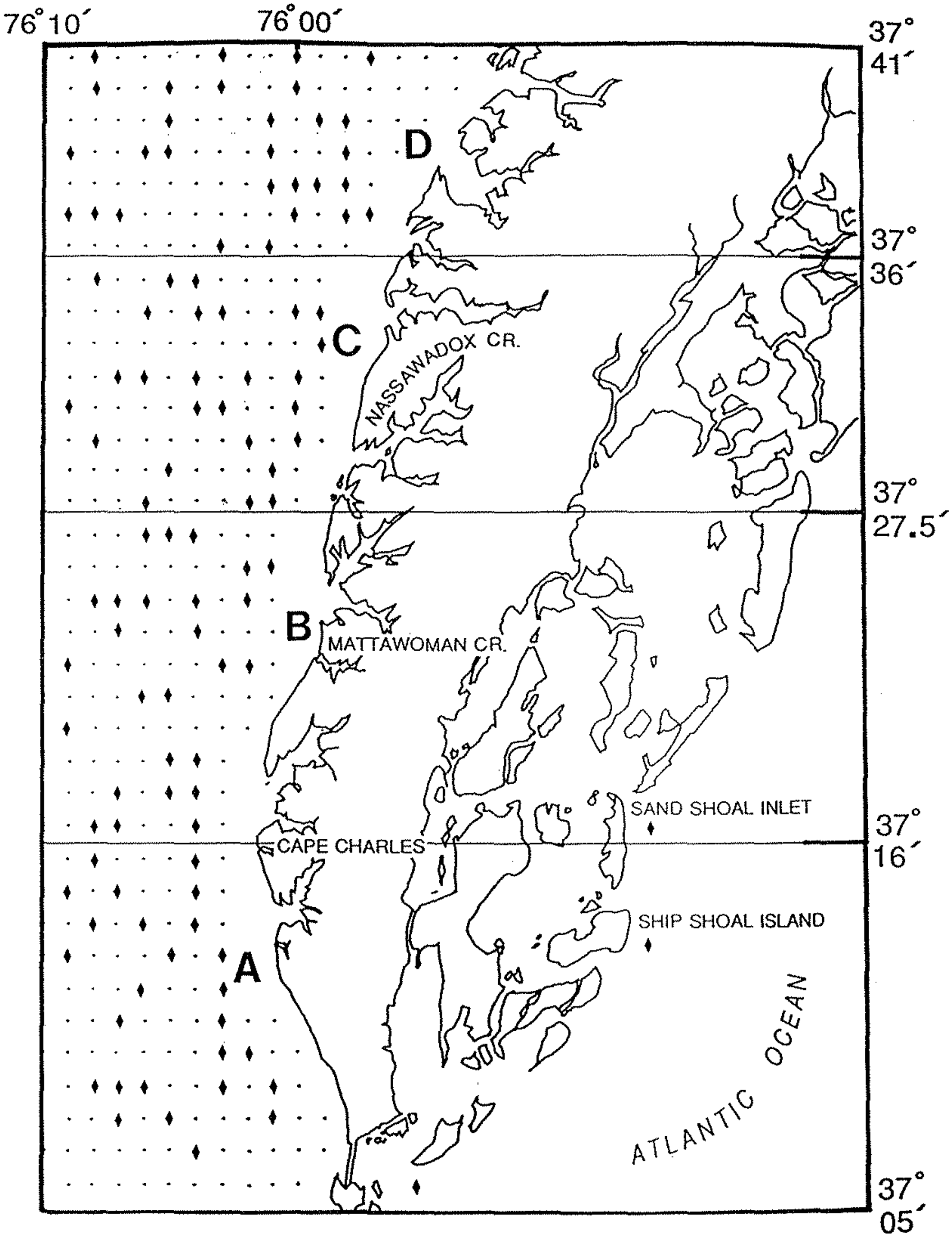

Figure 6. Ichthyoplankton survey grid. Triangles are stations occupied during eight surveys, April - May 1990. Some stations were occupied more than once.

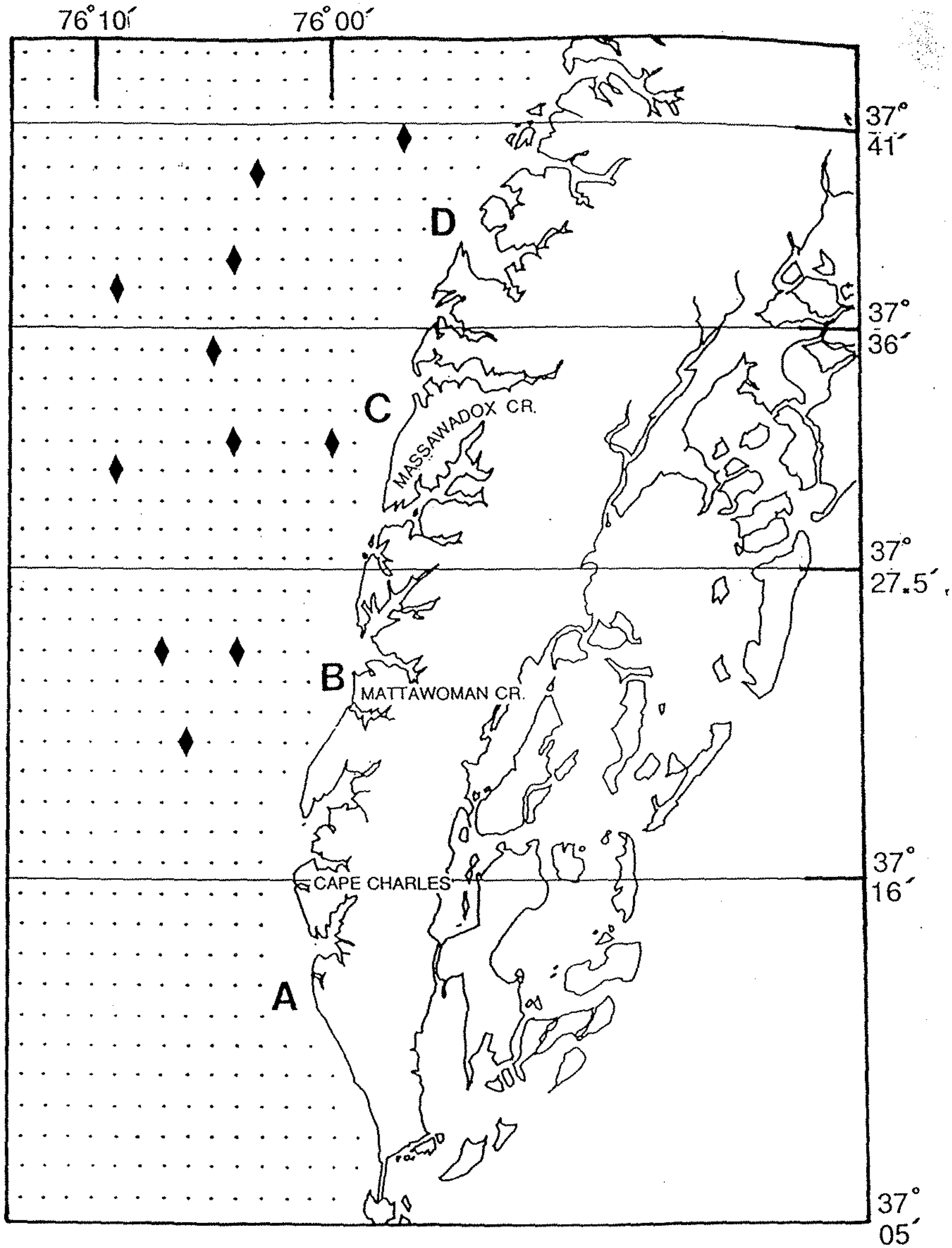

Figure 7. Stations occupied during BD90-01, 9 April 1990.

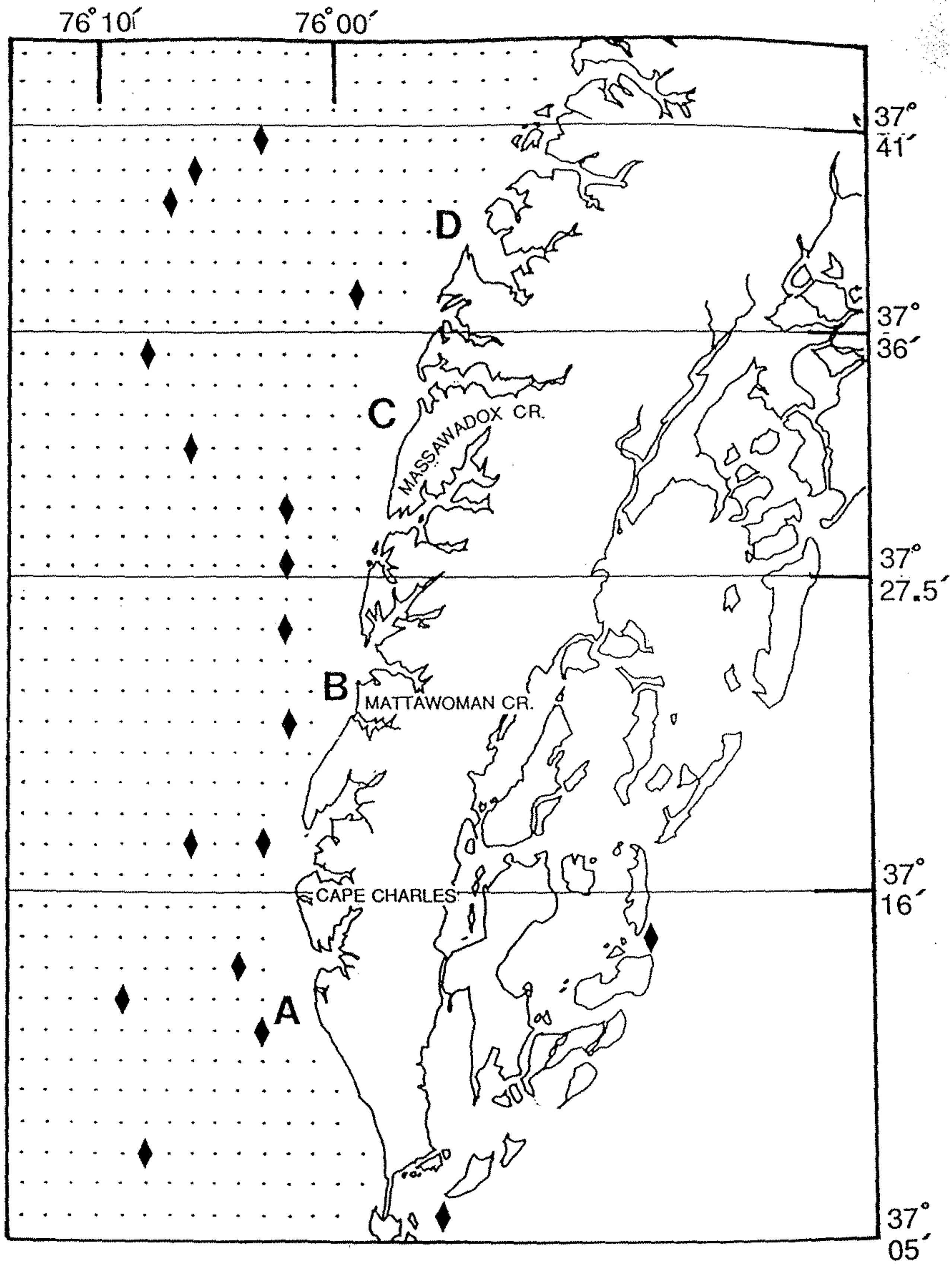

Figure 8. Stations occupied during BD90-02, 16 April 1990.

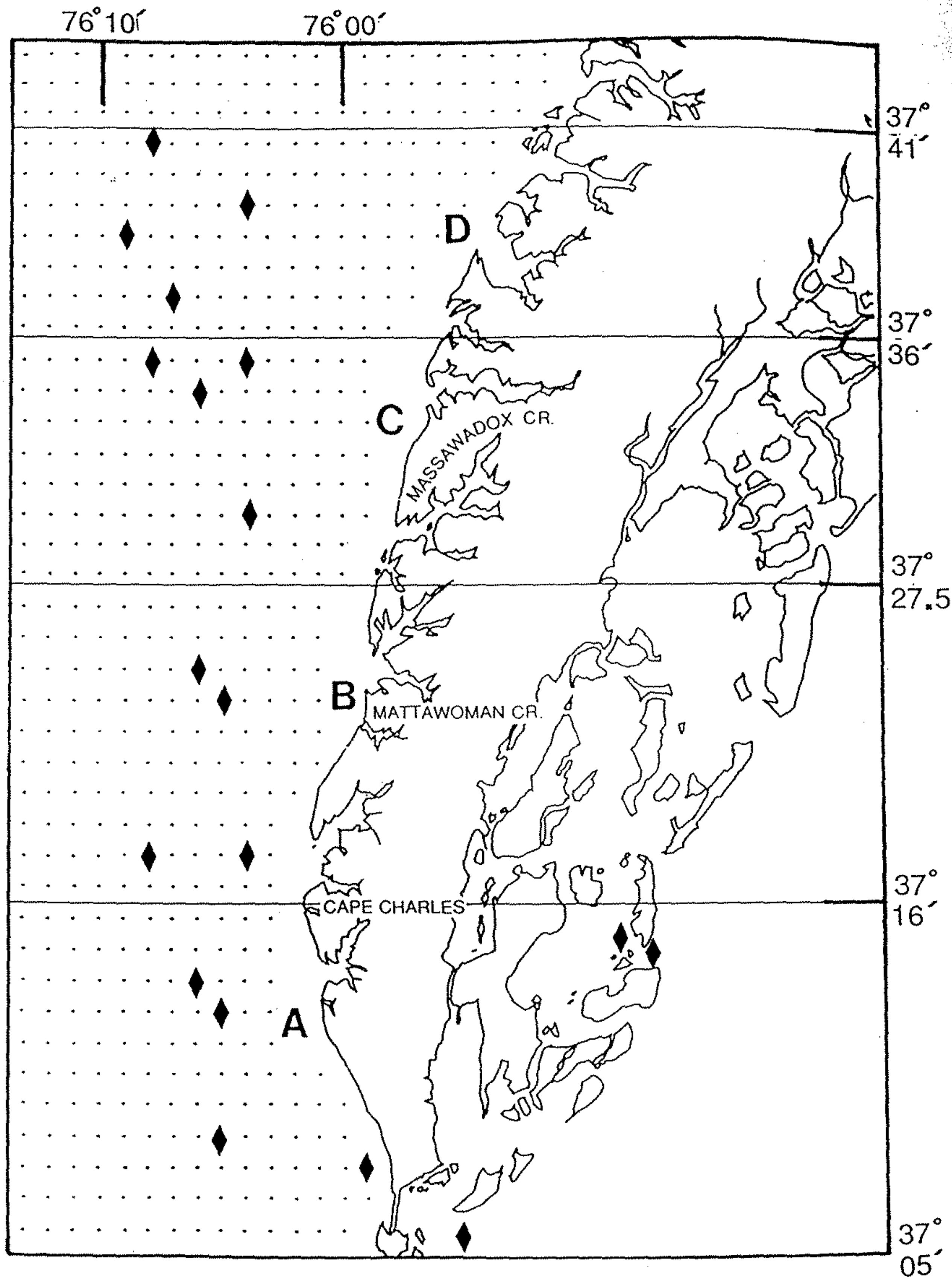

Figure 9. Stations occupied during BD90-03, 23 April 1990.

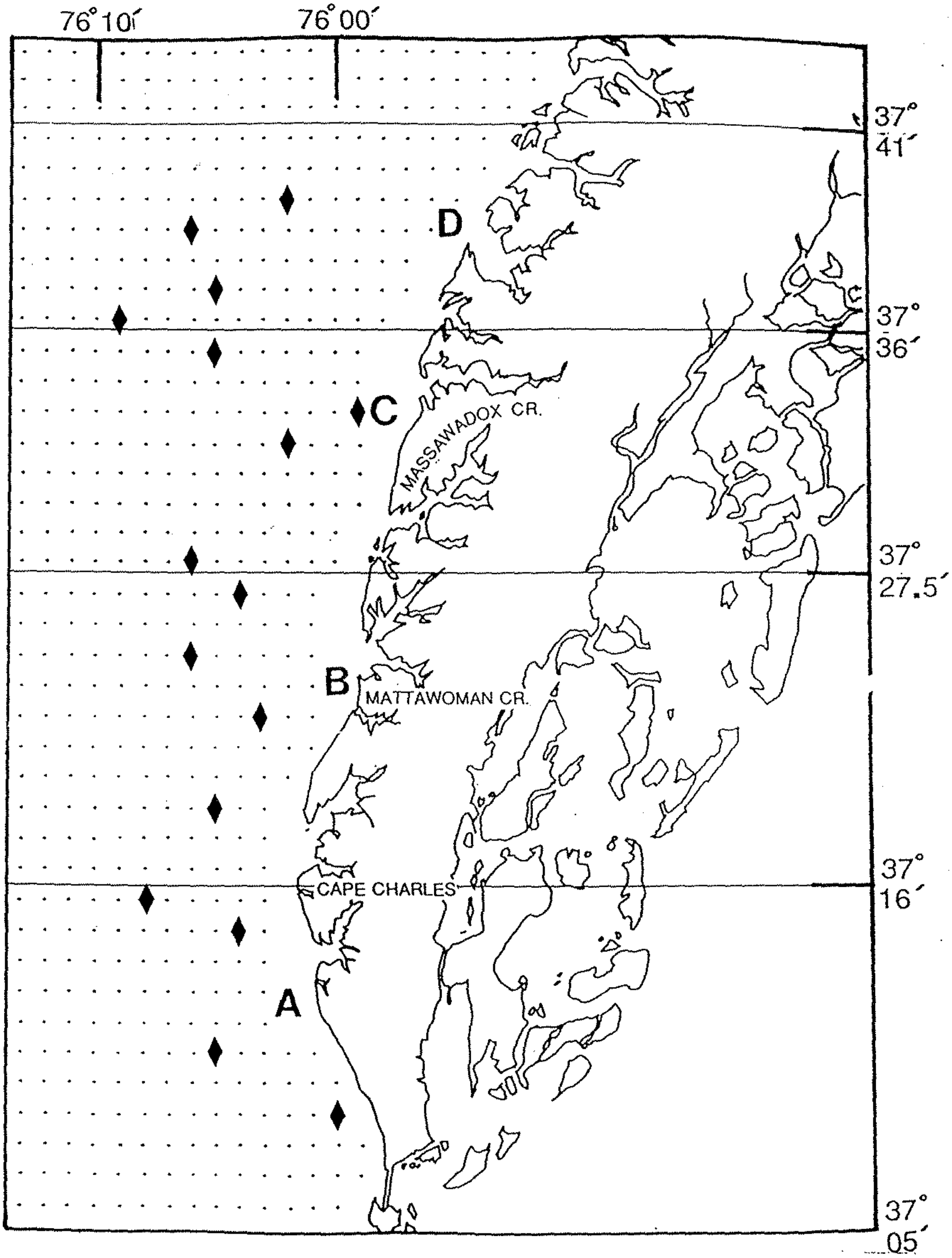

Figure 10. Stations occupied during BD90-04, 1 May 1990.

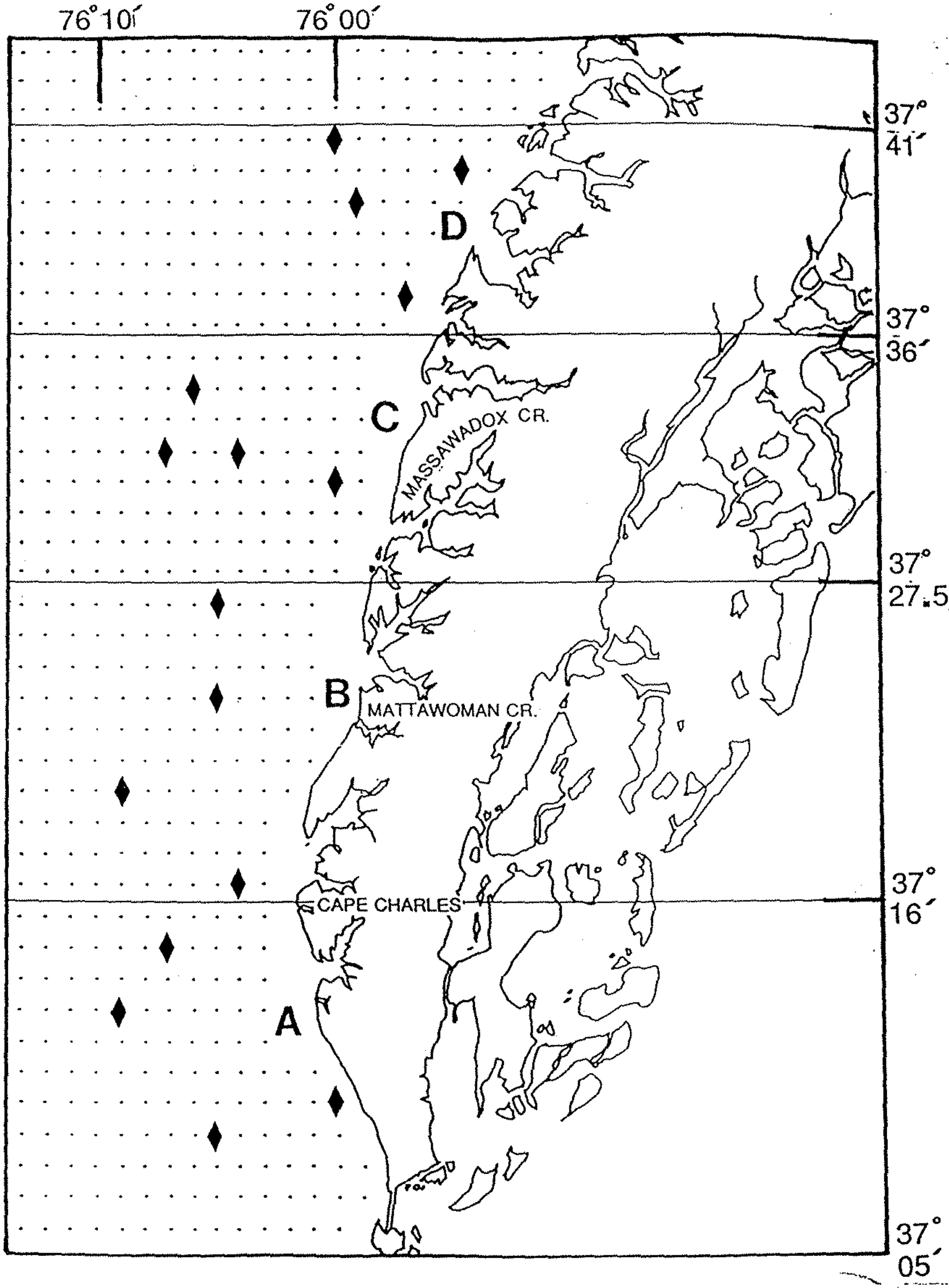

Figure 11. Stations occupied during BD90-05, 8 May 1990.

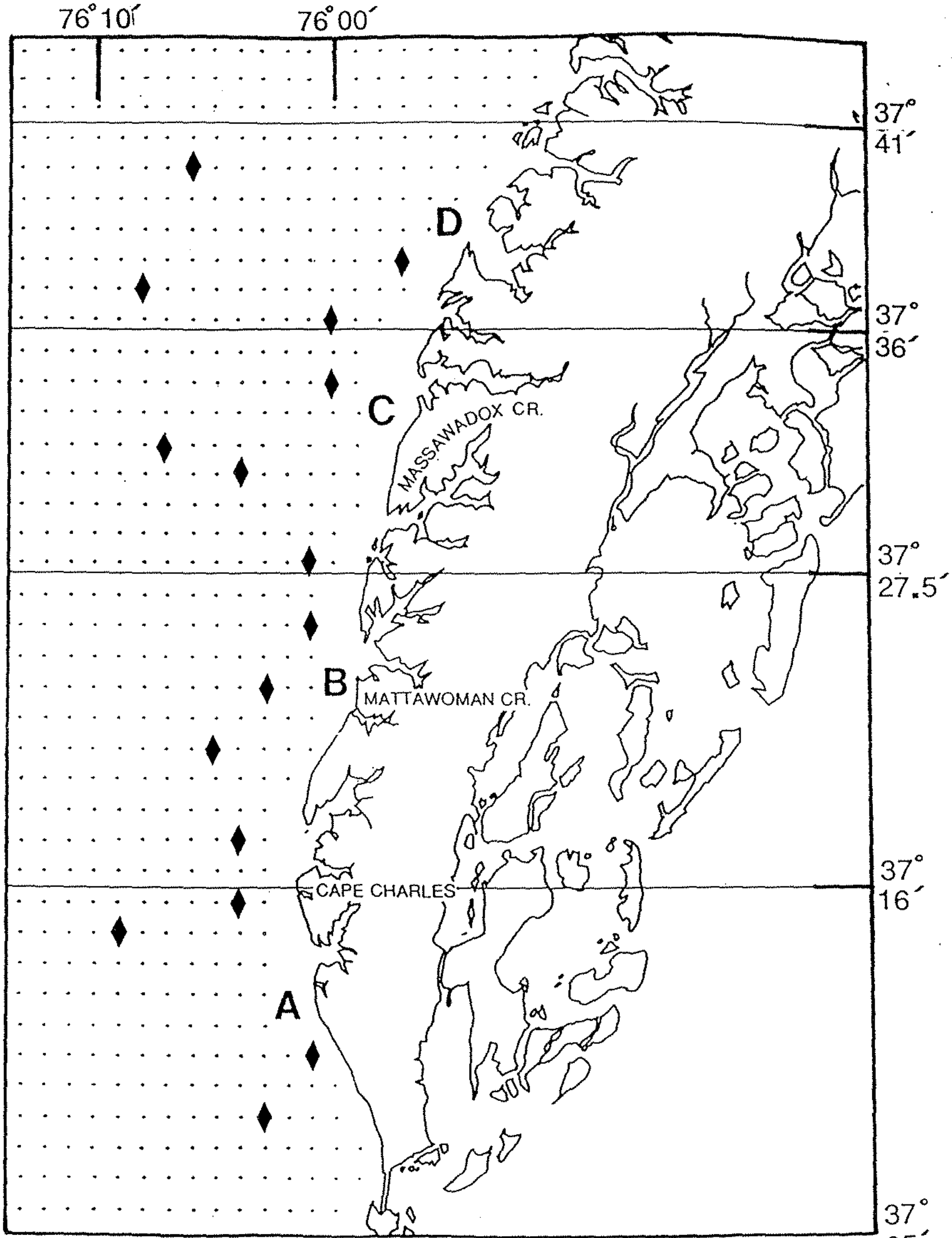

Figure 12. Stations occupied during BD90-06, 15 May 1990.

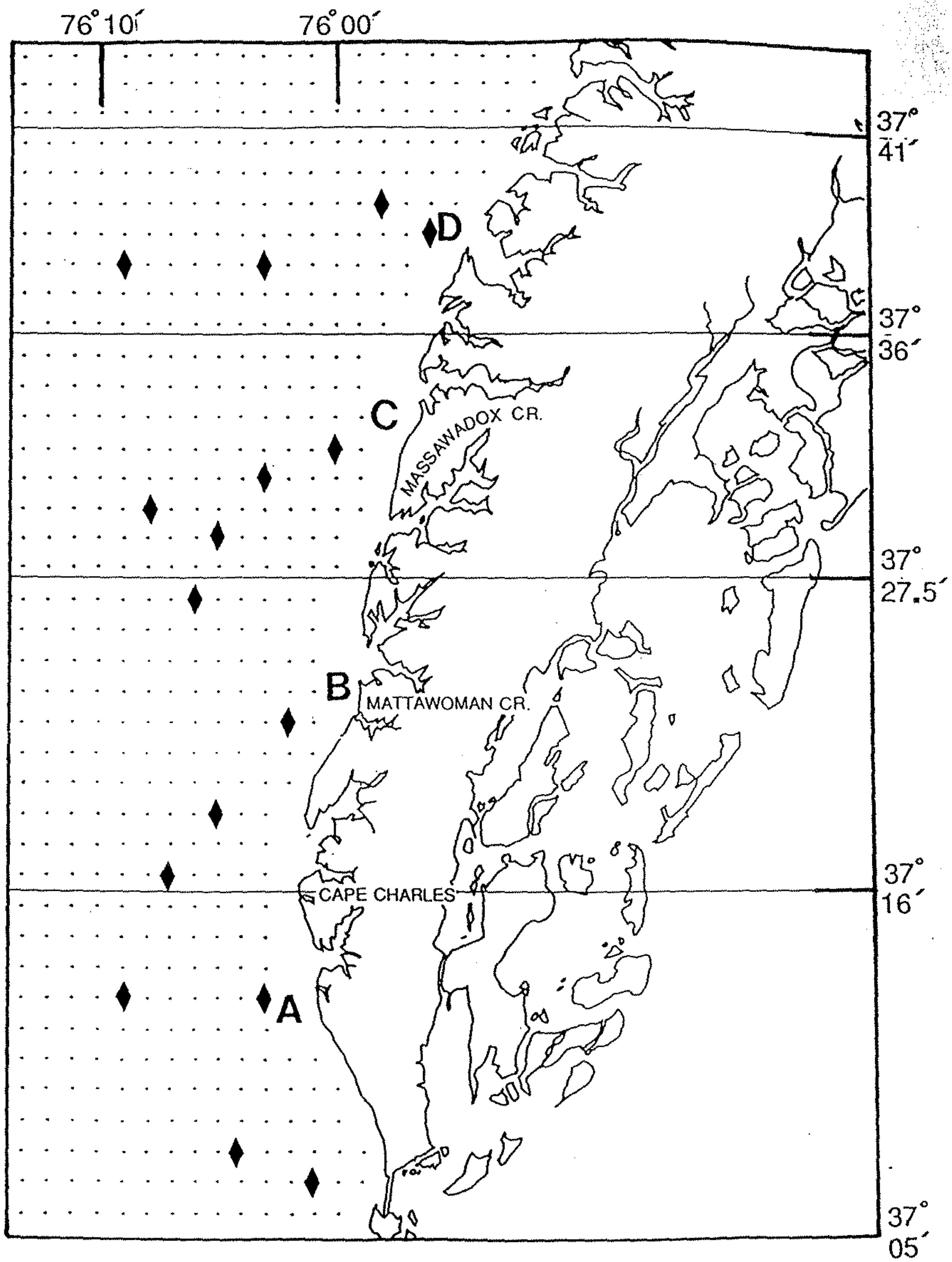

Figure 13. Stations occupied during BD90-08, 25 May 1990.

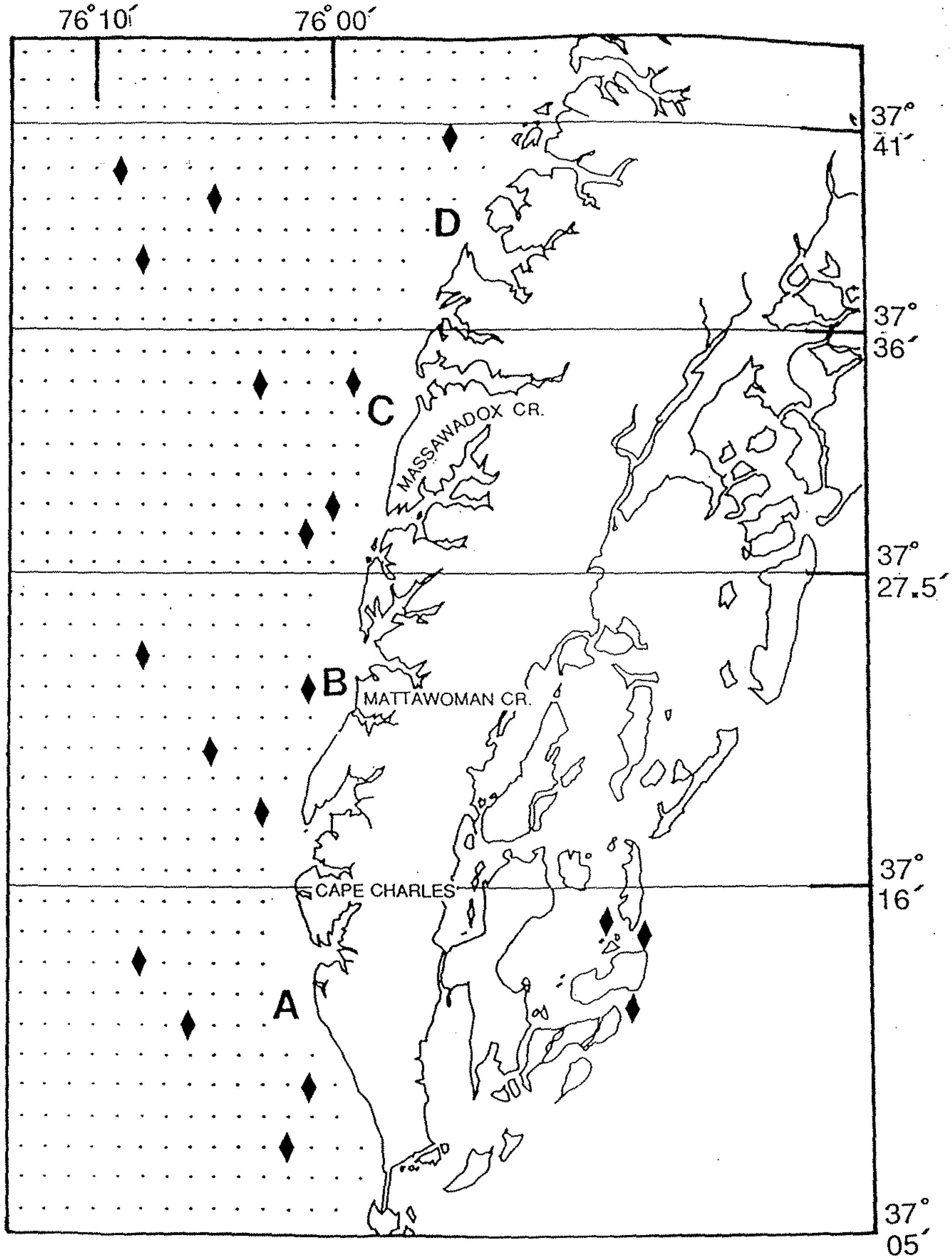

Figure 14. Stations occupied during BD90-09, 31 May 1990.

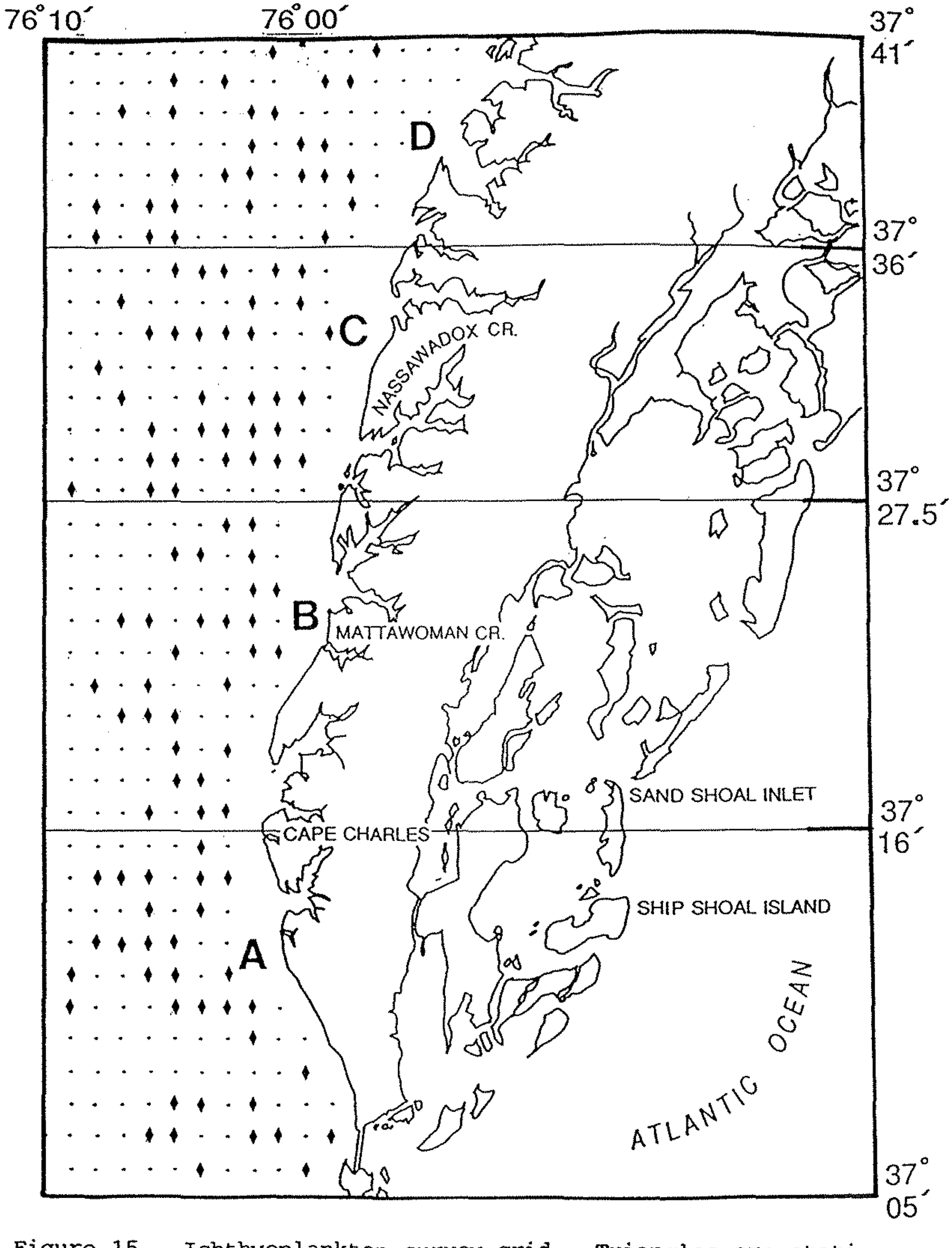

Figure 15. Ichthyoplankton survey grid. Triangles are stations occupied during nine surveys, April-May 1991. Some stations were occupied more than once.

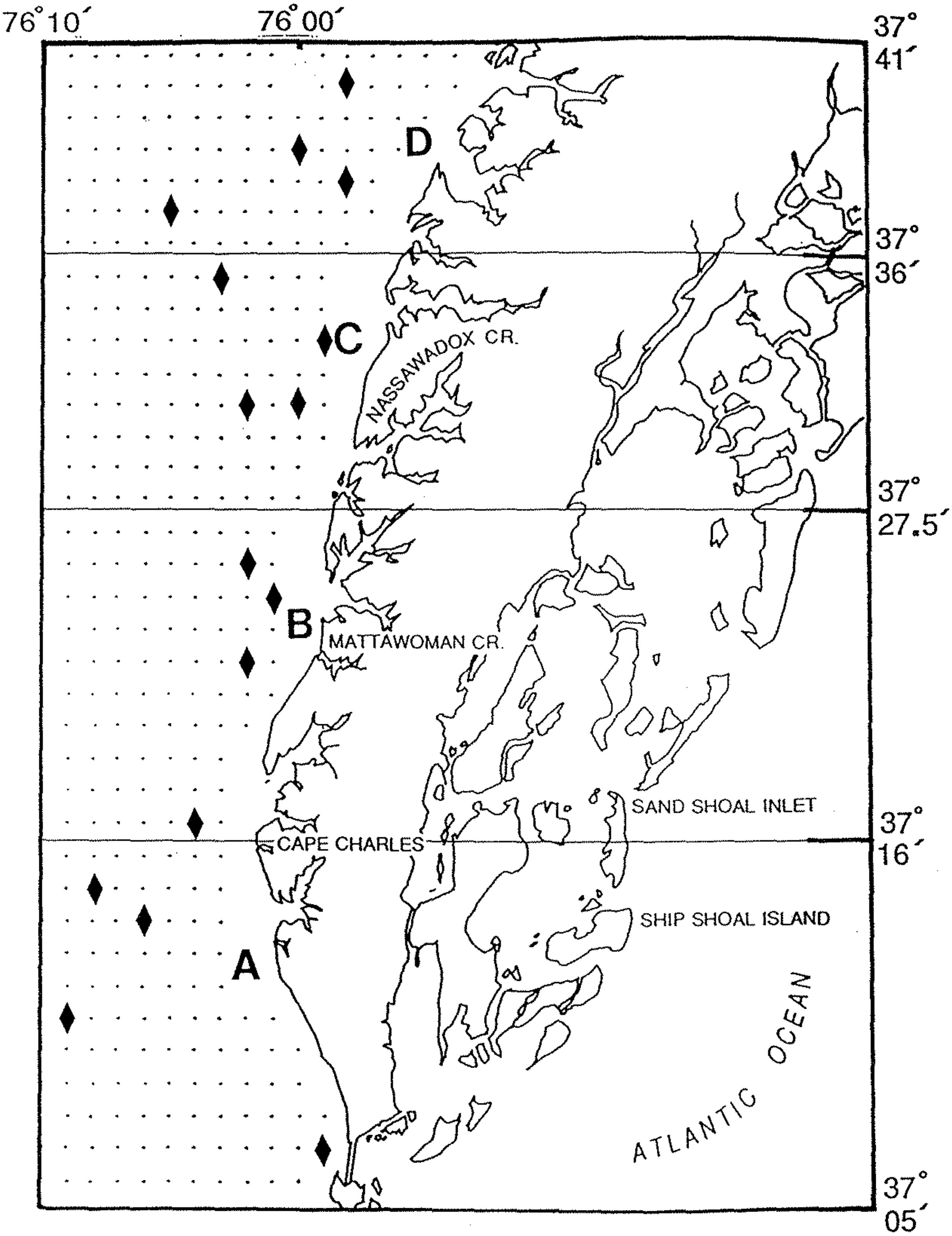

Figure 16. Stations occupied during BD91-01, 1 April 1991.

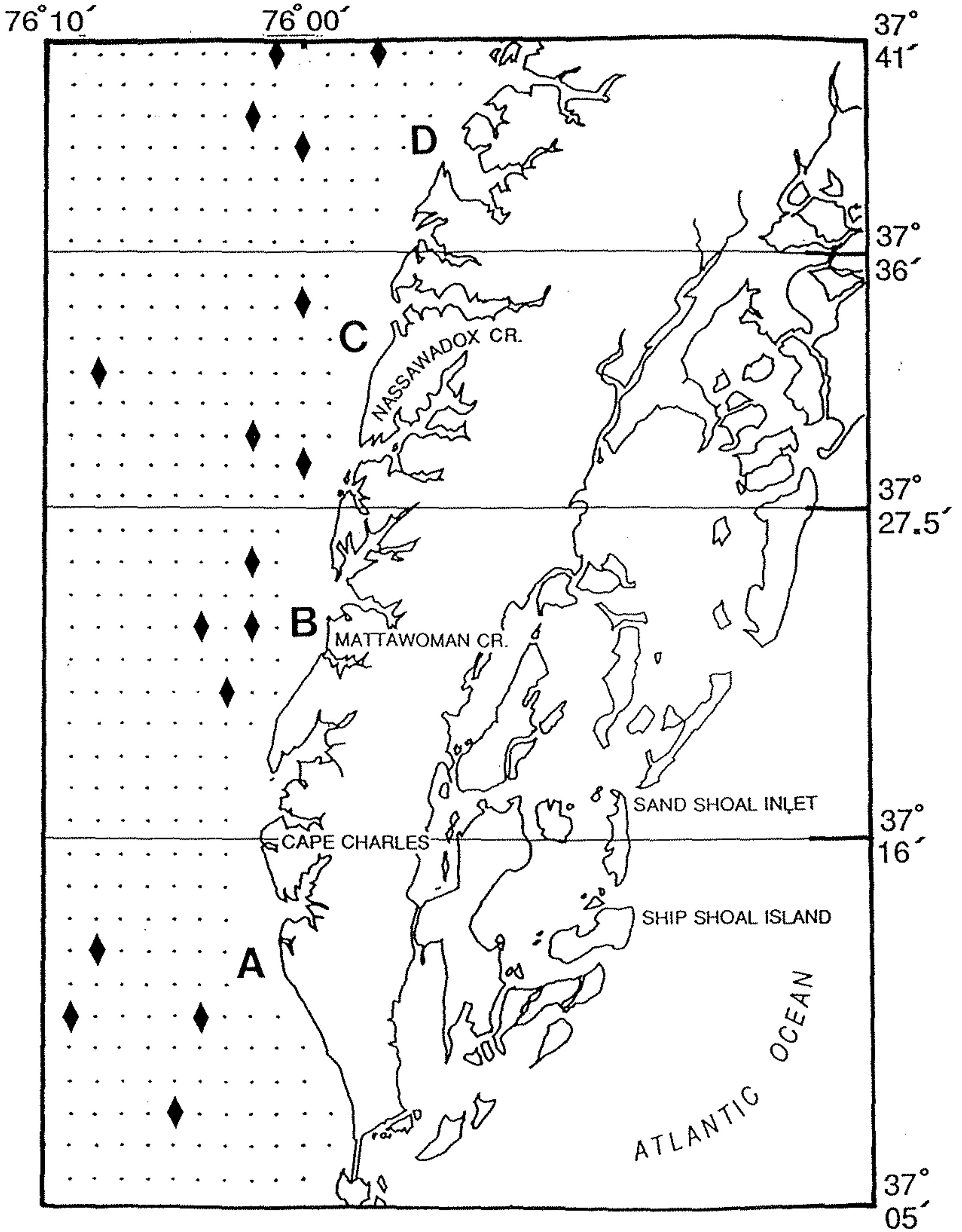

Figure 17. Stations occupied during BD91-02, 8 April 1991.

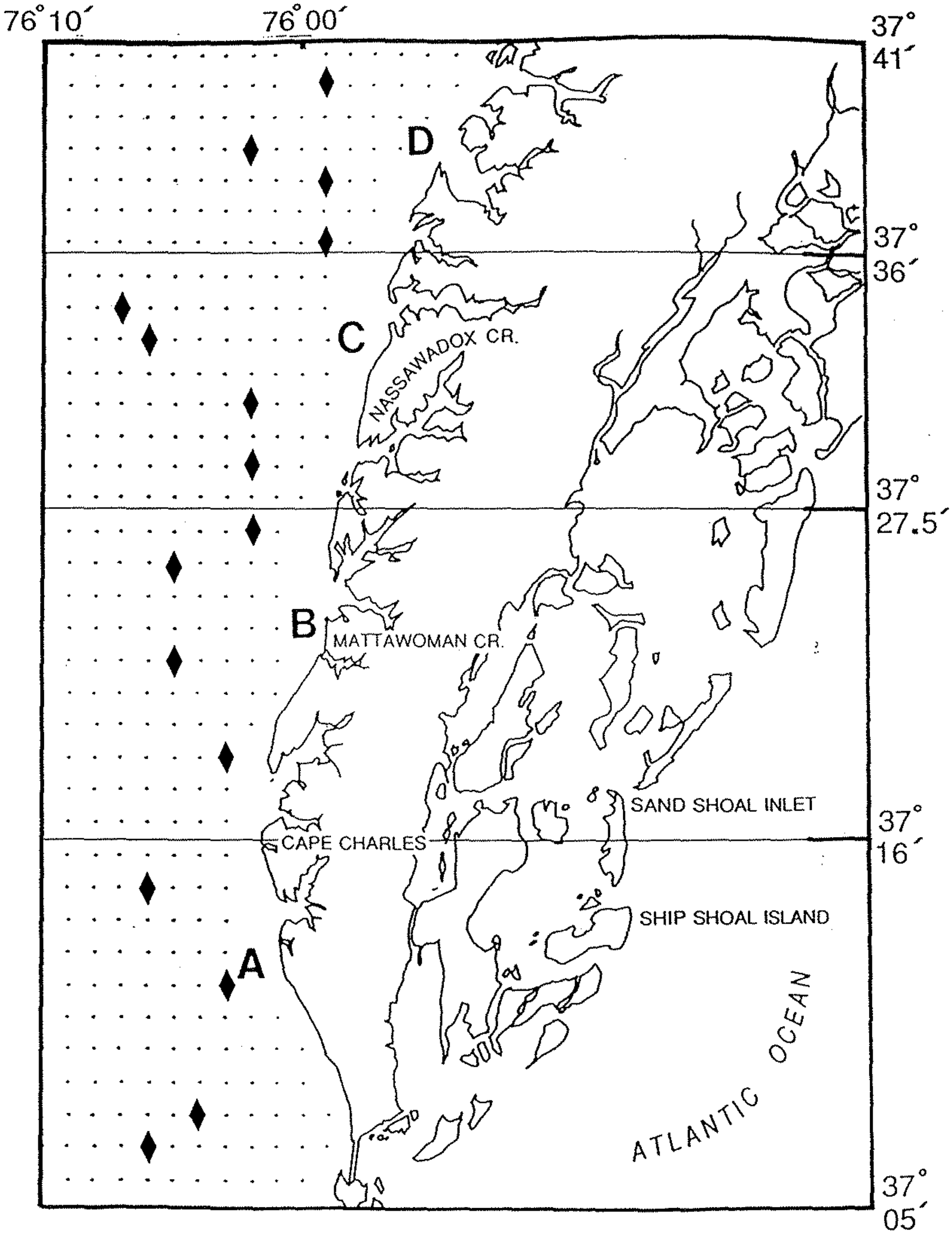

Figure 18. Stations occupied during BD91-03, 16 April 1991.

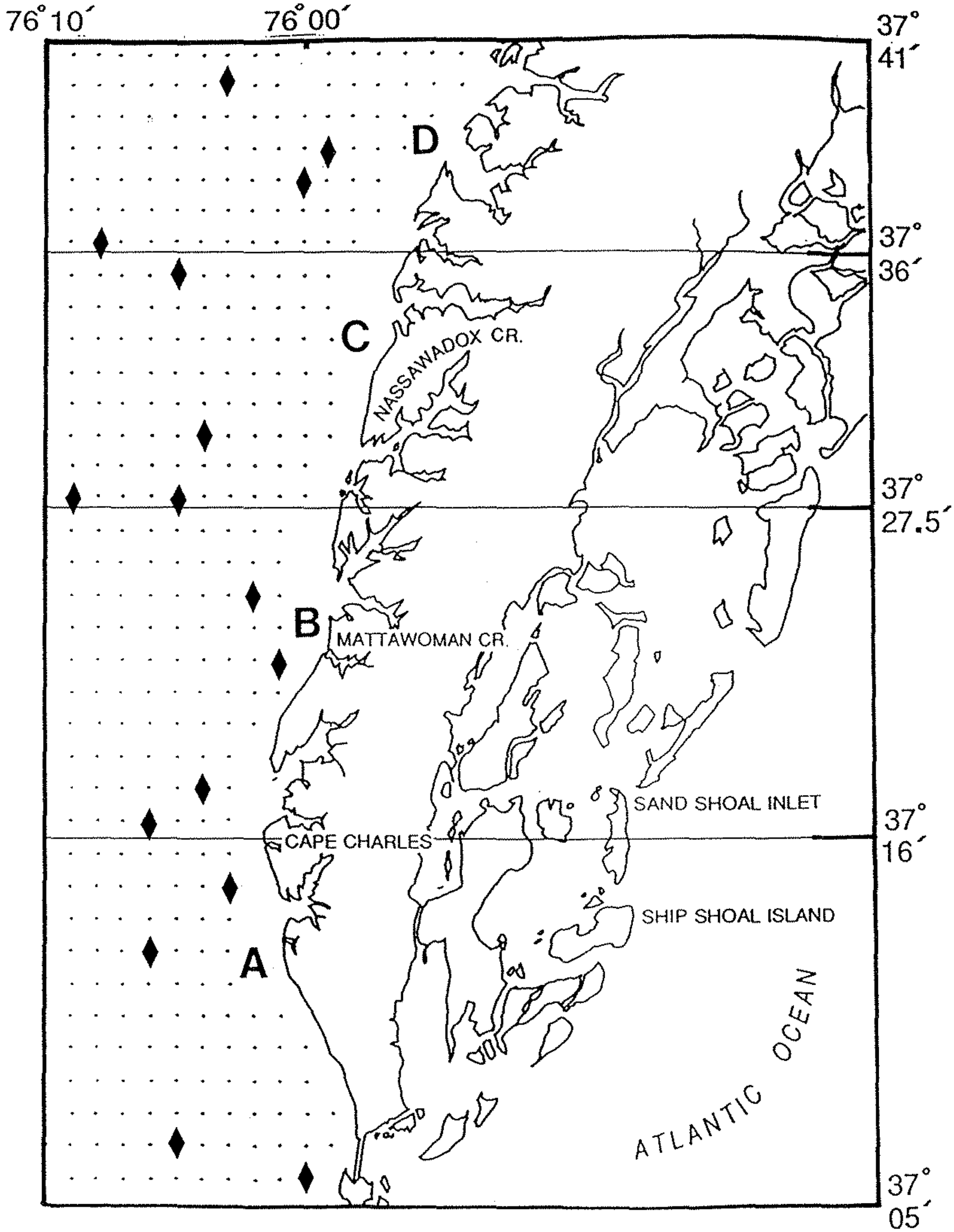

Figure 19. Stations occupied during BD91-04, 22 April 1991.

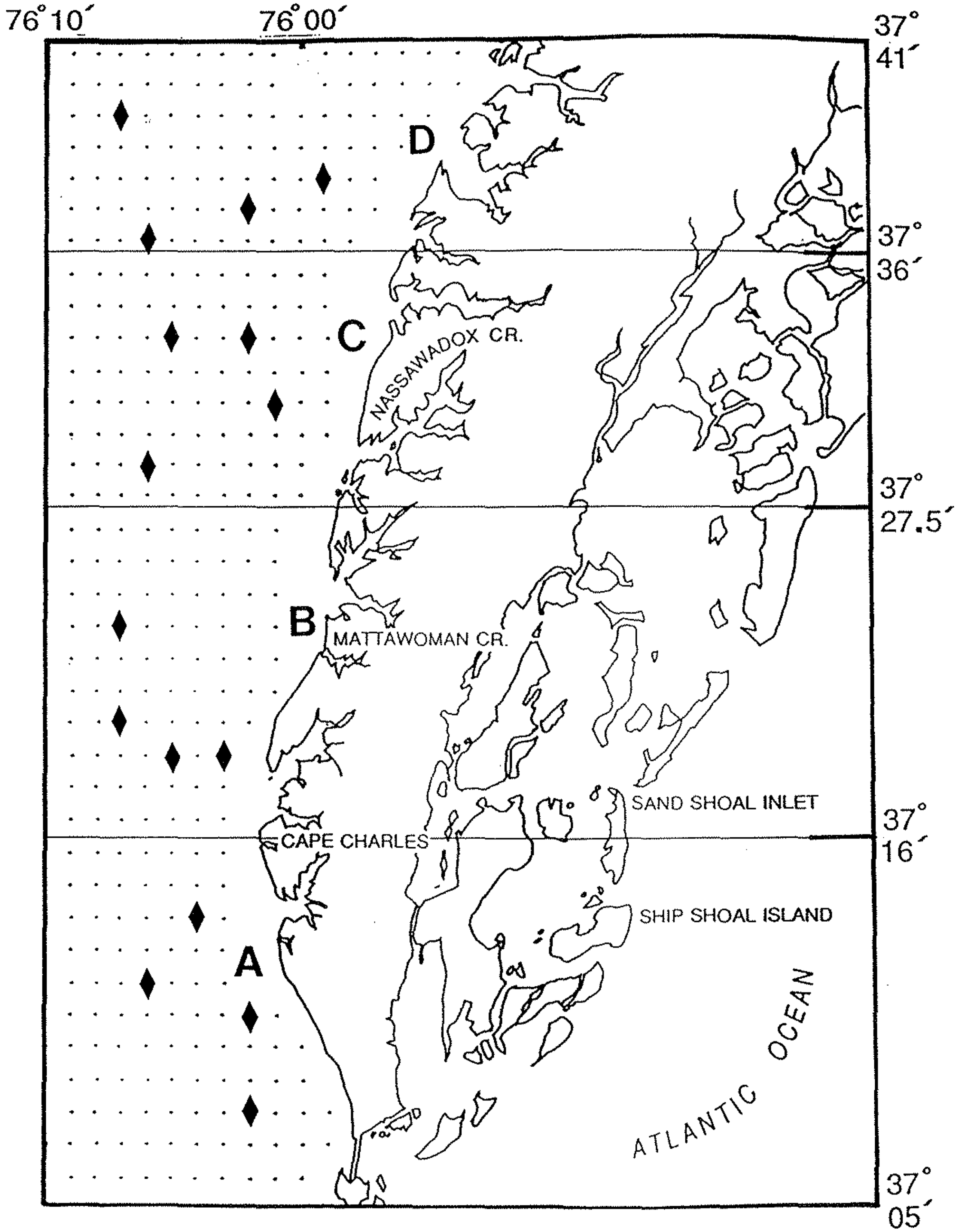

Figure 20. Stations occupied during BD91-05, 29 April 1991.

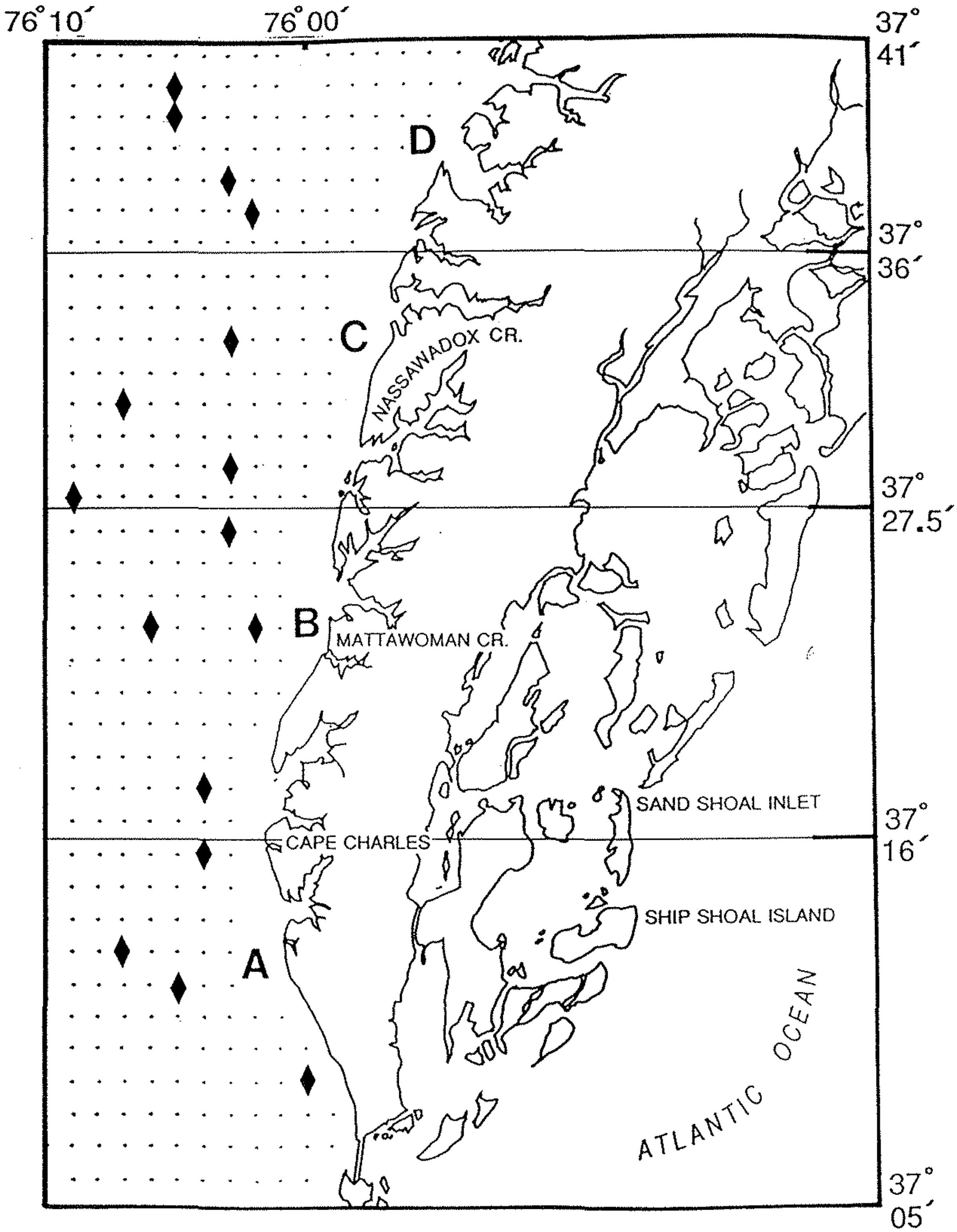

Figure 21. Stations occupied during BD91-06, 9 May 1991.

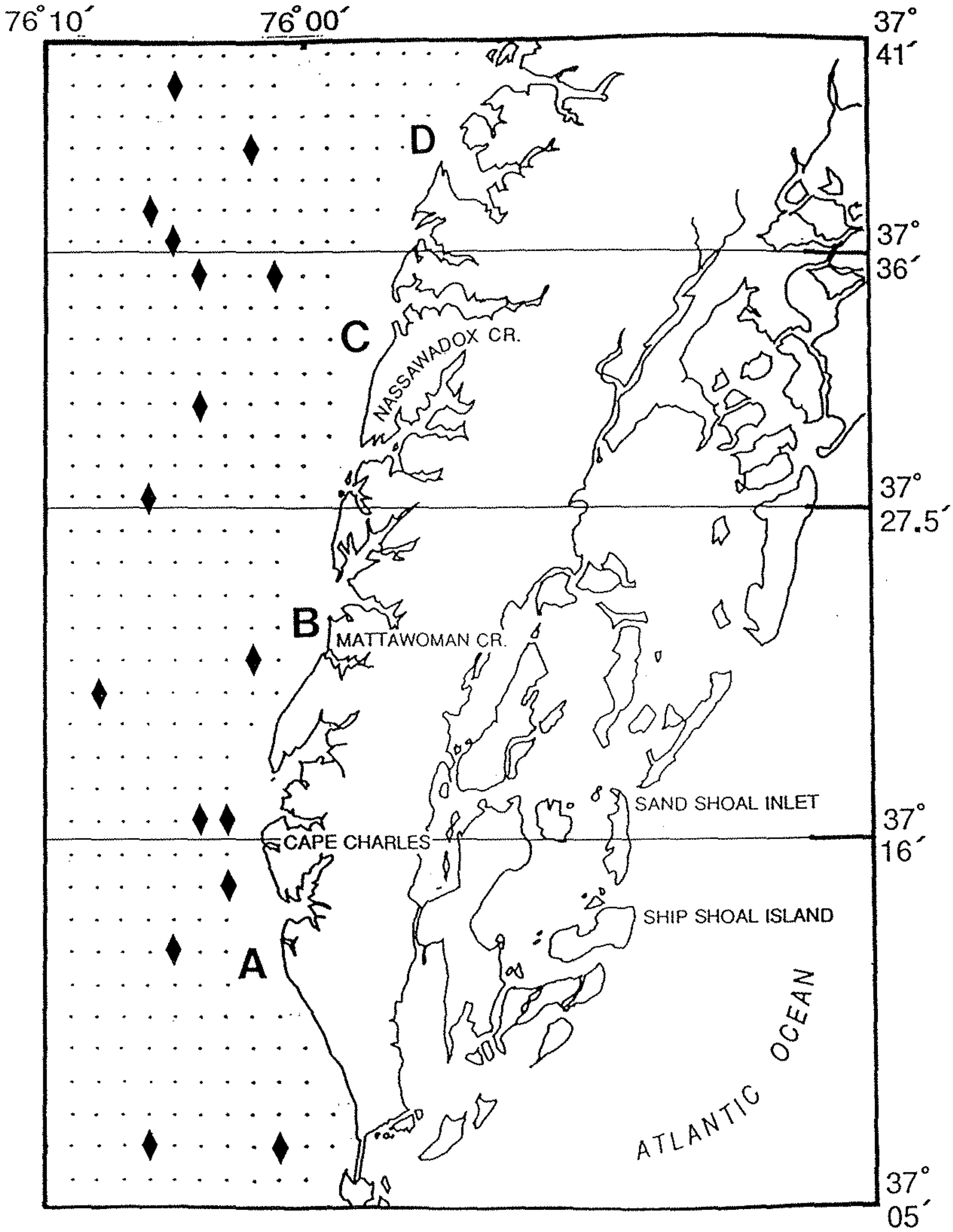

Figure 22. Stations occupied during BD91-07, 15 May 1991.

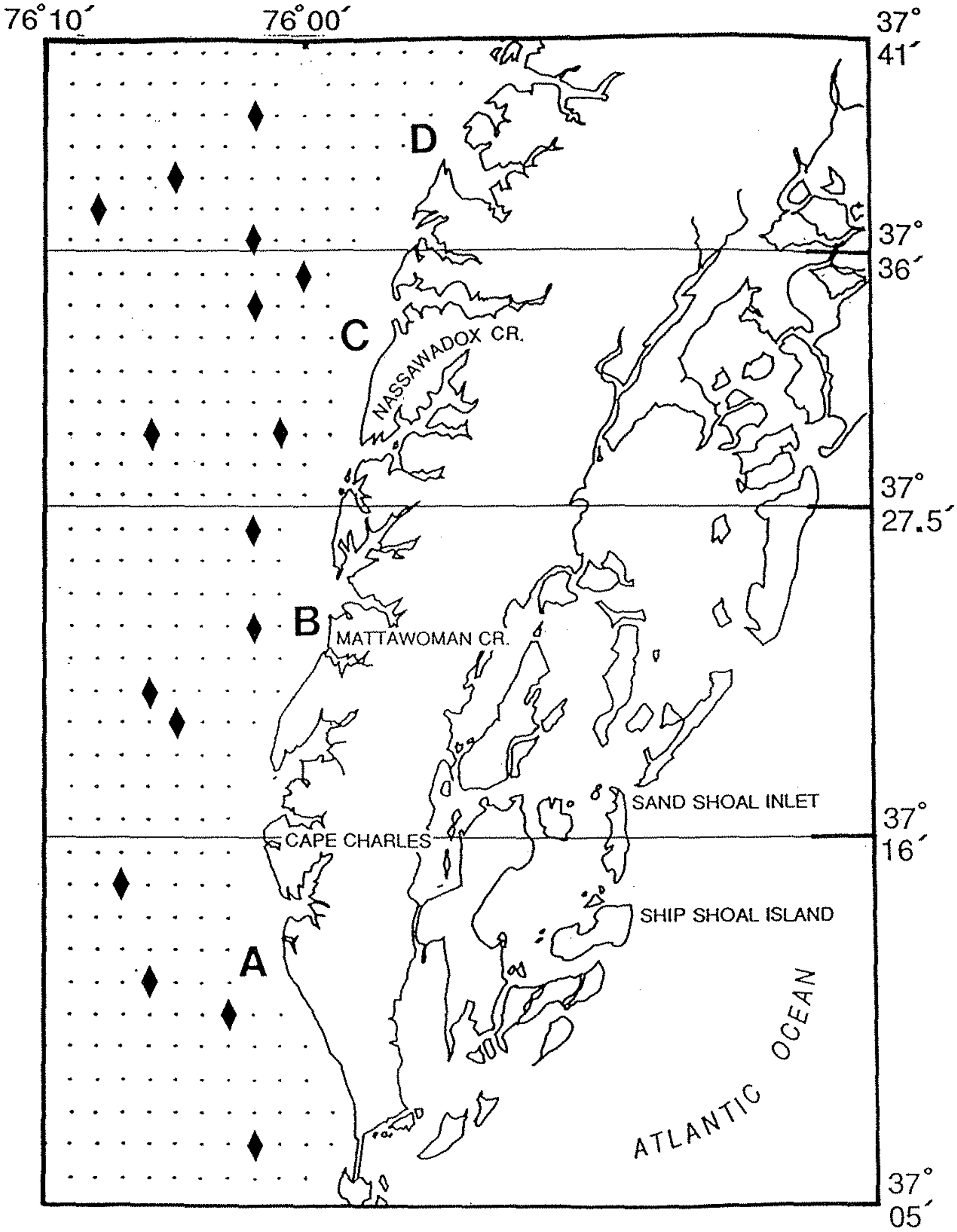

Figure 23. Stations occupied during BD91-09, 22 May 1991.

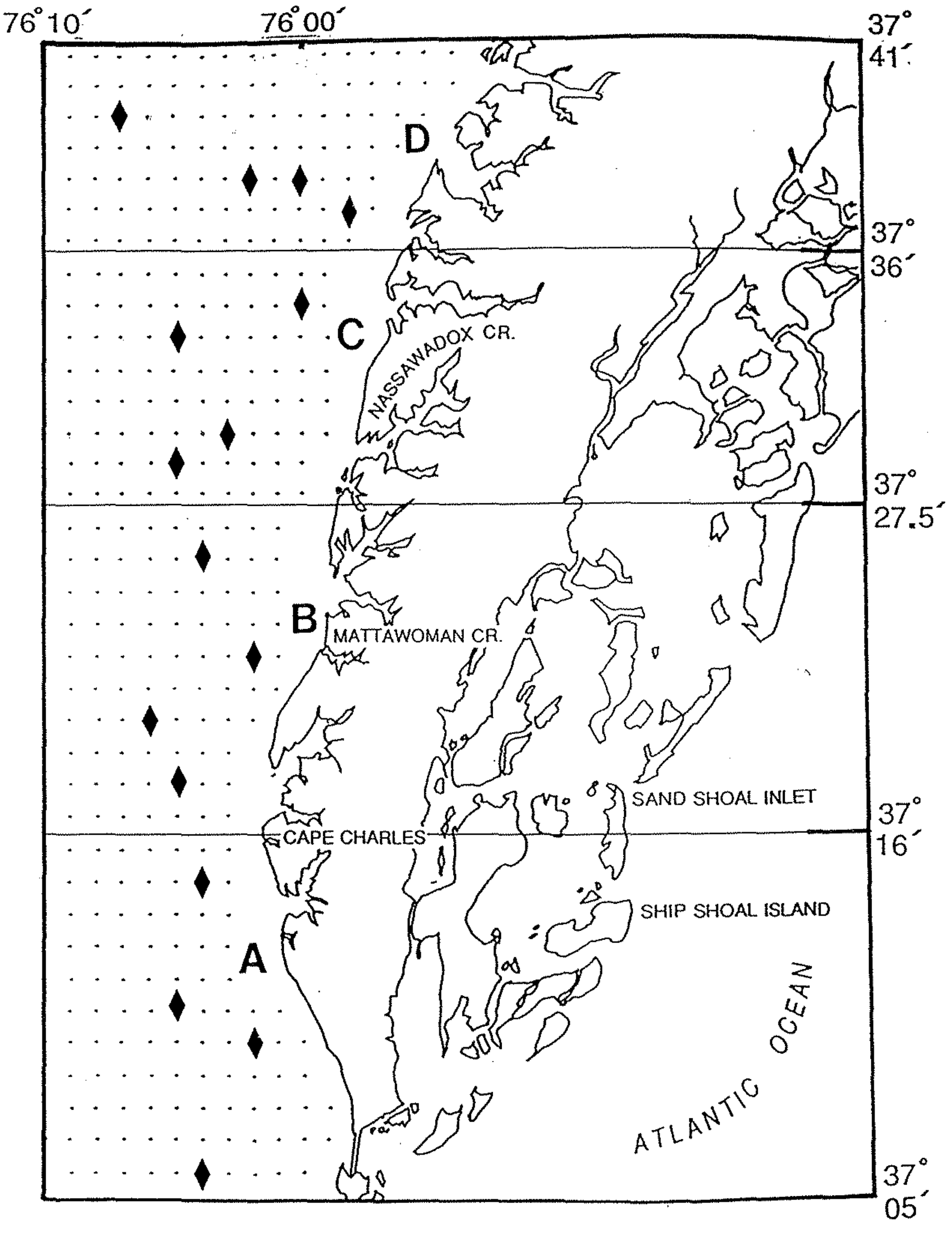

Figure 24. Stations occupied during BD91-10, 28 May 1991.

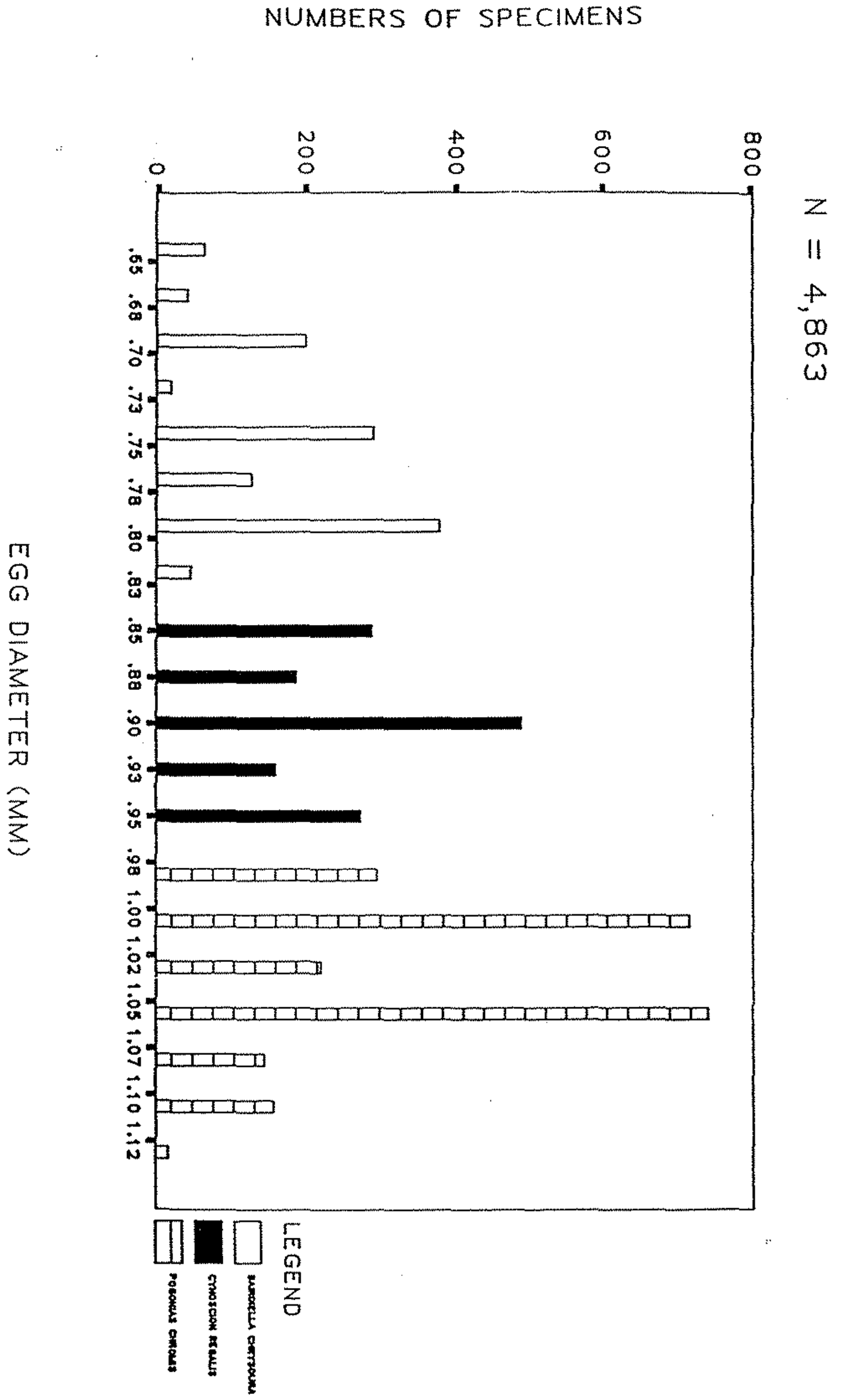

Figure 25. Histogram of egg diameters of all sciaenid eggs collected during the 1990 ichthyoplankton survey.

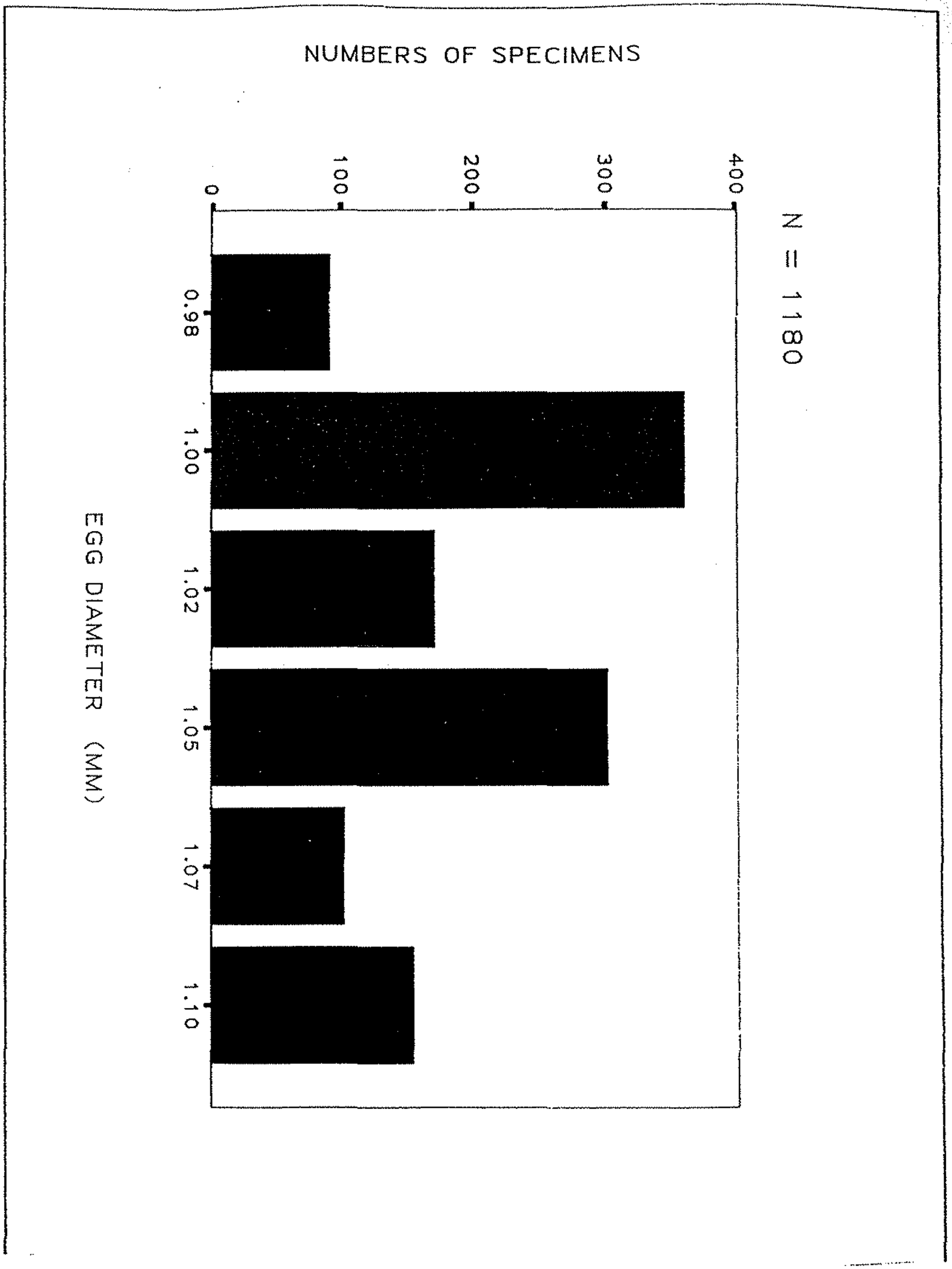

Figure 26. Histogram of egg diameters of black drum collected during the 1991 ichthyoplankton survey.

Table 2. Ichthyoplankton survey designations and station data.

Cruise	Date	Vessel	Total Stations	Total Eggs
BD90-01	9:IV:90	Bay Eagle	11*	0
BD90-02	16:IV:90	Bay Eagle	18**	0
BD90-03	23:IV:90	Bay Eagle	19**	1
BD90-04	1:V:90	Langley	16	274
BD90-05	8:V:90	Langley	16	58
BD90-06	15:V:90	Bay Eagle	16	279
BD90-07	19:V:90	Bay Eagle	16***	1280
BD90-08	25:V:90	Langley	16	153
BD90-09	31:V:90	Bay Eagle	19**	98
BD91-01	1:IV:91	Bay Eagle	16	0
BD91-02	8:IV:91	Bay Eagle	16	0
BD91-03	16:IV:91	Langley	16	0
BD91-04	22:IV:91	Bay Eagle	16	1
BD91-05	29:IV:91	Bay Eagle	16	169
BD91-06	9:V:91	Langley	16	464
BD91-07	15:V:91	Langley	16	781
BD91-08	21:V:91	Bay Eagle	16***	160
BD91-09	22:V:91	Bay Eagle	16	14
BD91-10	28:V:91	Bay Eagle	16	61
TOTAL			307	3793

* All stations not occupied due to data cable malfunction.

** Extra samples taken on the seaside of the eastern shore at Fisherman Island, Sand Shoal Inlet and Ship Shoal Inlet.

*** Time-series experiment.

collected during the 1990 sampling period. During several cruises in 1990, we also occupied the fixed stations in seaside inlets and many samples contained black drum eggs. This finding verifies spawning on the seaside of the eastern shore, however, the magnitude of spawning and the size of the spawning stock is presently unknown.

In 1991, spawning was observed from 23 April to 30 May with peak spawning again occurring around 15 May, however, average water column temperatures were slightly depressed (17.88°C). Egg densities at positive stations were similar between years. Altogether, 1,740 eggs of black drum were collected of which 499 were taken during peak spawning on 15 May. Black drum spawned in April and May of 1990 - 1991 in the area from Fisherman Island to just below Tangier Island in lower Chesapeake Bay and in Sand Shoal, Ship Shoal and Fisherman Island Inlets. The greatest intensity of spawning was observed in an area off Cape Charles harbor. Tables 3 and 4 report densities of eggs (mean abundance and ranges observed) in each stratum during the two-year period. In each year, areas of greatest abundance of eggs was localized and positive stations were most numerous in Strata A and B. Overall, egg densities at positive stations ranged from 0.1 to 37.9 eggs m^{-2}. Spawning commenced in mid- to late April when mean water column temperatures reached 9 to 10°C.

Densities of larvae identified as black drum in 1990 and 1991 were low (0.02 - 0.3 m^3) (Table 5 and 6) and many of the sciaenids removed from samples were yolk-sac larvae that were unidentifiable to species. Larger specimens of other sciaenid larvae that were identifiable to species were limited to silver perch, <u>Bairdiella chrysoura</u> and weakfish, <u>Cynoscion regalis</u>. Figures 27 and 28 depict the stations where sciaenid larvae were collected during 1990 and 1991 ichthyoplankton cruises.

Maps of egg distributions were constructed (Figures 29 - 33, 1990; Figures 34 - 39, 1991) to depict weekly variability in spawning location. The location of positive stations during the entire spawning season are depicted in Figure 40, 1990 and Figure 41, 1991. Raw data used to calculate 1990 and 1991 total, seasonal egg production are presented in Tables 6 and

Table 3. Mean abundance and range of egg densities (eggs/m^2) by stratum for the 1990 ichthyoplankton survey.

Cruise	Mean	Range	Positive Stations
BD90-03-A	----	----	----
BD90-03-B	----	----	----
BD90-03-C	0.18	0.18	1
BD90-03-D	----	----	----
BD90-04-A	12.7	0.1 - 37.9	3
BD90-04-B	9.5	0.6 - 26.8	3
BD90-04-C	0.2	0.1 - 0.2	2
BD90-04-D	0.6	0.5 - 0.7	2
BD90-05-A	0.4	0.1 - 0.6	4
BD90-05-B	1.7	1.0 - 2.4	3
BD90-05-C	0.4	0.2 - 0.9	3
BD90-05-D	0.1	0.1	1
BD90-06-A	2.2	0.1 - 7.7	4
BD90-06-B	16.0	6.3 - 28.0	3
BD90-06-C	0.5	0.2 - 0.7	3
BD90-06-D	0.2	0.2 - 0.3	2
BD90-08-A	0.9	0.8 - 1.0	3
BD90-08-B	1.8	0.1 - 4.8	4
BD90-08-C	0.8	0.3 - 1.2	2
BD90-08-D	3.3	0.9 - 6.5	4
BD90-09-A	0.2	0.1 - 0.4	4
BD90-09-B	1.2	0.2 - 3.1	3
BD90-09-C	2.4	1.6 - 3.5	3
BD90-09-D	0.9	0.9	1

Table 4. Mean abundance and range of egg densities (eggs/m^2) by stratum for the 1991 ichthyoplankton survey.

Cruise	Mean	Range	Positive Stations
BD91-04-A	0.1	0.1	1
BD91-04-B	----	----	----
BD91-04-C	----	----	----
BD91-04-D	----	----	----
BD91-05-A	3.6	0.2 - 4.1	4
BD91-05-B	3.2	0.2 - 7.7	4
BD91-05-C	0.4	0.4	1
BD91-05-D	----	----	----
BD91-06-A	9.6	0.2 - 30.0	4
BD91-06-B	0.5	0.3 - 0.6	2
BD91-06-C	----	----	----
BD91-06-D	0.6	0.2 - 0.9	3
BD91-07-A	6.2	0.1 - 13.7	4
BD91-07-B	5.4	0.7 - 15.8	4
BD91-07-C	----	----	----
BD91-07-D	0.5	0.5	1
BD91-09-A	0.2	0.1 - 0.3	4
BD91-09-B	0.3	0.1 - 0.5	2
BD91-09-C	0.3	0.1 - 0.5	2
BD91-09-D	----	----	----
BD91-10-A	1.5	0.1 - 2.9	4
BD91-10-B	6.0	1.7 - 10.3	2
BD91-10-C	1.1	0.4 - 2.0	3
BD91-10-D	0.3	0.2 - 0.4	2

Table 5. Data summary of sciaenid larvae collected during the 1990 ichthyoplankton survey. Length is reported in millimeters, Number is the total number of specimens in a collection, Density is reported as larvae/100m^3. P.c. = Pogonias cromis; Y.s. = yolk sac larvae; B.c. = Bairdiella chrysoura; C.r. = Cynoscion regalis.

Location	Date	Species	Length	Number	Density
B83	8:V:90	P.c.	2.9	1	1.35
Time 3	19:V:90	P.c.	2.5	1	1.80
Time 9	19:V:90	P.c.	2.4	1	1.42
Time 12	19:V:90	P.c.	2.7	1	1.66
Time 15	20:V:90	P.c.	2.5	1	1.23
B4	24:V:90	P.c.	2.4	1	1.69
B67	24:V:90	P.c.	2.6	1	1.45
B80	24:V:90	P.c.	2.2	1	1.14
A22	24:V:90	P.c.	2.7	1	1.18
A84	24:V:90	P.c.	2.6	1	1.58
B36	31:V:90	P.c.	3.3	1	1.95
A32	31:V:90	P.c.	3.5	1	1.07
S.S.I.	1:VI:90	P.c.	2.4	1	1.77
Total		P.c.	2.2-3.5	13	
A6	15:V:90	B.c.	2.6	1	1.56
B75	15:V:90	B.c.	2.0-2.6	2	3.61
TIME 3	19:V:90	B.c.	2.3	1	1.80
TIME 6	19:V:90	B.c.	2.4-2.6	2	4.14
TIME 9	19:V:90	B.c.	1.8-2.1	4	5.68
TIME 12	19:V:90	B.c.	2.0	1	1.66
TIME 15	20:V:90	B.c.	2.0-2.4	3	3.70
TIME 21	20:V:90	B.c.	2.0	1	1.77
TIME 24	20:V:90	B.c.	2.0-2.1	2	3.89
A22	20:V:90	B.c.	2.5	1	1.18
A28	20:V:90	B.c.	1.3	1	1.73
A84	20:V:90	B.c.	2.0-2.1	2	3.16

Total		B.c.	1.3-2.6	21	
A8	15:V:90	Y.s.	1.6-1.8	3	5.35
A6	15:V:90	Y.s.	1.5-2.4	15	23.48
B75	15:V:90	Y.s.	1.5-1.9	4	7.21
B50	15:V:90	Y.s.	1.6-2.1	9	15.20
B34	15:V:90	Y.s.	1.6-1.7	3	5.57
Time 3	19:V:90	Y.s.	1.7	1	1.80
Time 6	19:V:90	Y.s.	1.6-1.8	9	18.65
Time 9	19:V:90	Y.s.	1.5-2.0	11	15.63
Time 12	19:V:90	Y.s.	1.6-1.8	22	36.54
Time 15	20:V:90	Y.s.	1.6-1.8	5	6.17
Time 21	20:V:90	Y.s.	1.6-1.8	4	7.09
Time 24	20:V:90	Y.s.	1.6-1.7	2	3.89
B67	24:V:90	Y.s.	1.7-2.2	19	27.65
B80	24:V:90	Y.s.	1.6-2.1	3	3.42
A22	24:V:90	Y.s.	1.6-1.8	3	3.53
A28	24:V:90	Y.s.	1.8-2.0	2	3.46
A84	24:V:90	Y.s.	1.6-2.0	14	22.13
A32	31:V:90	Y.s.	1.6-1.7	2	2.13
S.S.I.*	1:VI:90	Y.s.	1.5-1.9	2	3.89
Total		Y.s.	1.5-2.4	133	
Time 18	20:V:90	C.r.	2.6	1	1.44
D64	31:V:90	C.r.	2.3	1	1.79
Total		C.r.	2.3-2.6	2	

* S.S.I. = Ship Shoal Inlet on the seaside of Virginia's eastern shore.

Table 6. Data summary of sciaenid larvae collected during the 1991 ichthyoplankton survey. Length is reported in millimeters, Number is the total number of specimens in a collection, Density is reported as larvae/100m^3. P.c. = Pogonias cromis; Y.s. = yolk-sac larvae; B.c. = Bairdiella chrysoura; C.r. = Cynoscion regalis.

Location	Date	Species	Length	Number	Density
A63	10:V:91	P.c.	5.1	1	1.49
B82	15:V:91	P.c.	4.5	1	1.05
B8	22:V:91	P.c.	5.0	1	1.34
Total		P.c.	4.5-5.1	3	
A14	15:V:91	B.c.	4.1	1	1.24
B44	15:V:91	B.c.	4.1	1	1.25
A82	22:V:91	B.c.	5.5	1	1.48
Total		B.c.	4.1-5.5	3	
B35	9:V:91	Y.s.	2.0-3.2	2	2.79
B82	9:V:91	Y.s.	2.4-2.8	3	5.34
A63	10:V:91	Y.s.	1.8-2.0	3	4.47
A84	15:V:91	Y.s.	2.0-2.4	24	31.98
B82	15:V:91	Y.s.	3.2-3.8	18	18.89
TIME 6	21:V:91	Y.s.	3.2-3.8	8	11.67
TIME 12	21:V:91	Y.s.	3.0-3.1	2	3.25
TIME 21	22:V:91	Y.s.	3.0	1	1.50
A82	22:V:91	Y.s.	3.1-3.6	5	7.43
A52	29:V:91	Y.s.	3.1	1	2.92
Total		Y.s.	1.8-3.8	67	
B82	15:V:91	C.r.	4.4	1	1.05
Time 0	21:V:91	C.r.	4.3	1	1.70
Time 24	22:V:91	C.r.	4.5	1	1.87
B59	22:V:91	C.r.	4.5	1	1.43
A42	22:V:91	C.r.	Damaged	1	1.14
A82	22:V:91	C.r.	4.8	1	1.48
Total		C.r.	4.3-4.8	6	

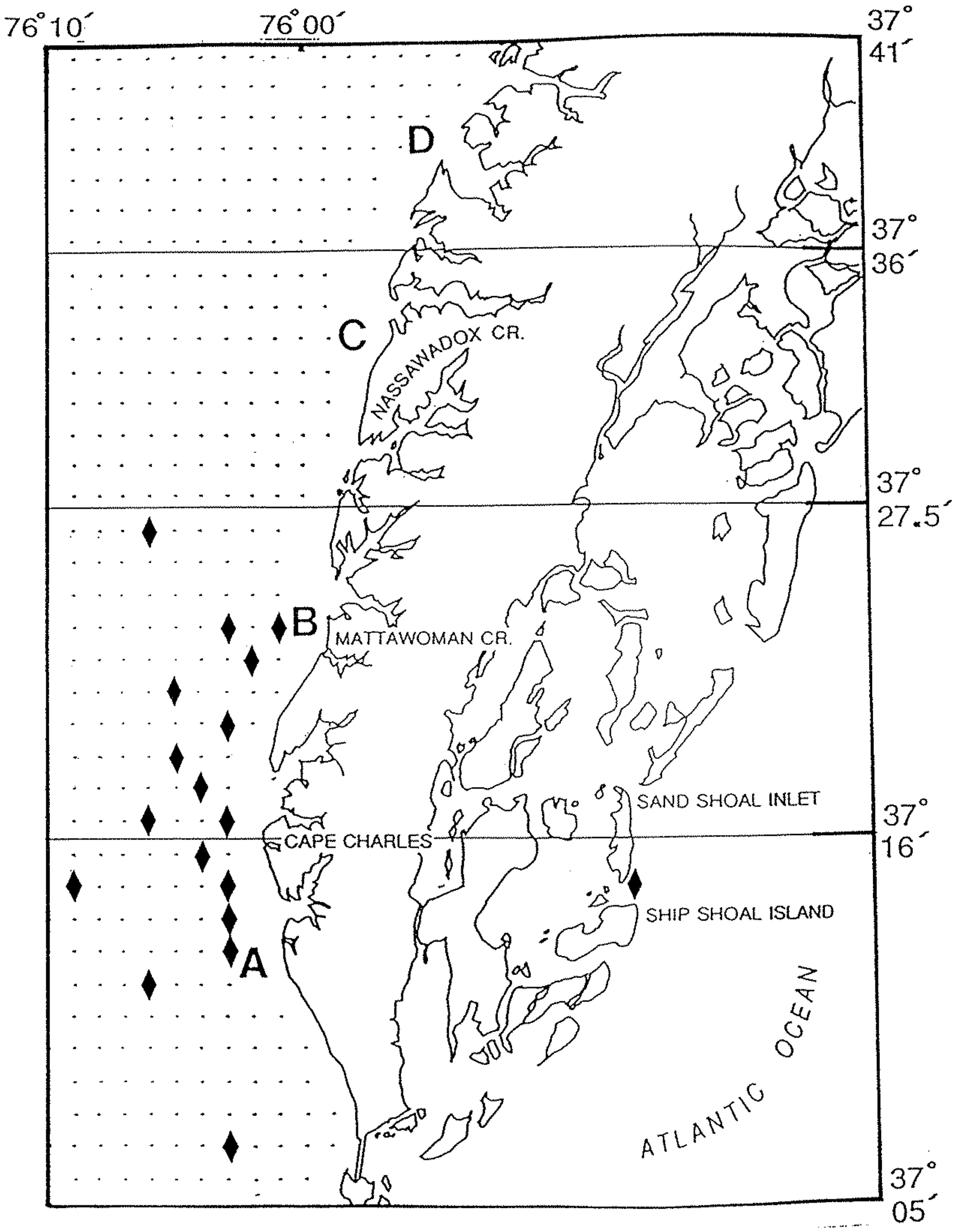

Figure 27. Ichthyoplankton survey grid. Triangles represent stations where sciaenid larvae occurred, April - May 1990.

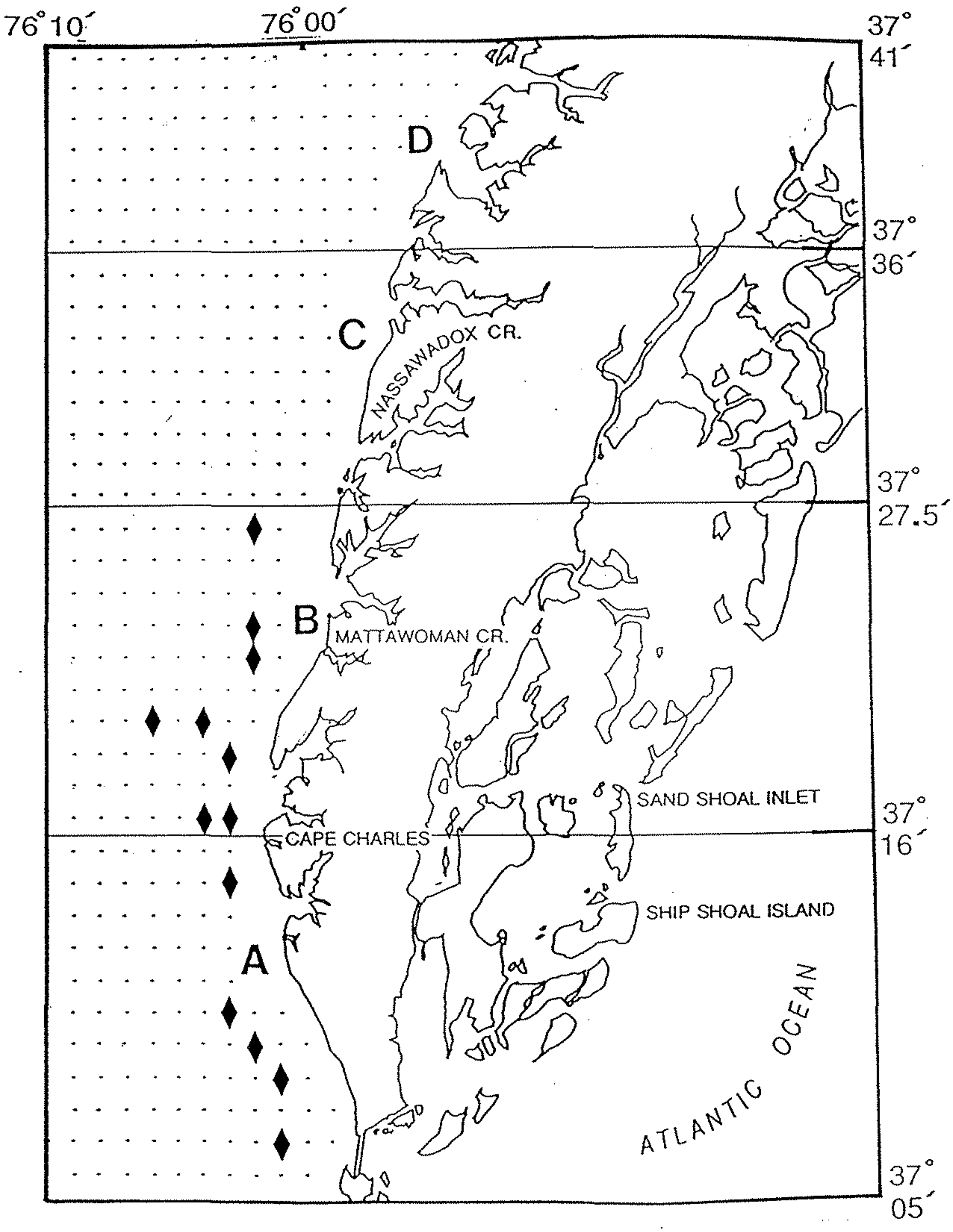

Figure 28. Ichthyoplankton survey grid. Triangles represent stations where sciaenid larvae occurred, April - May 1991.

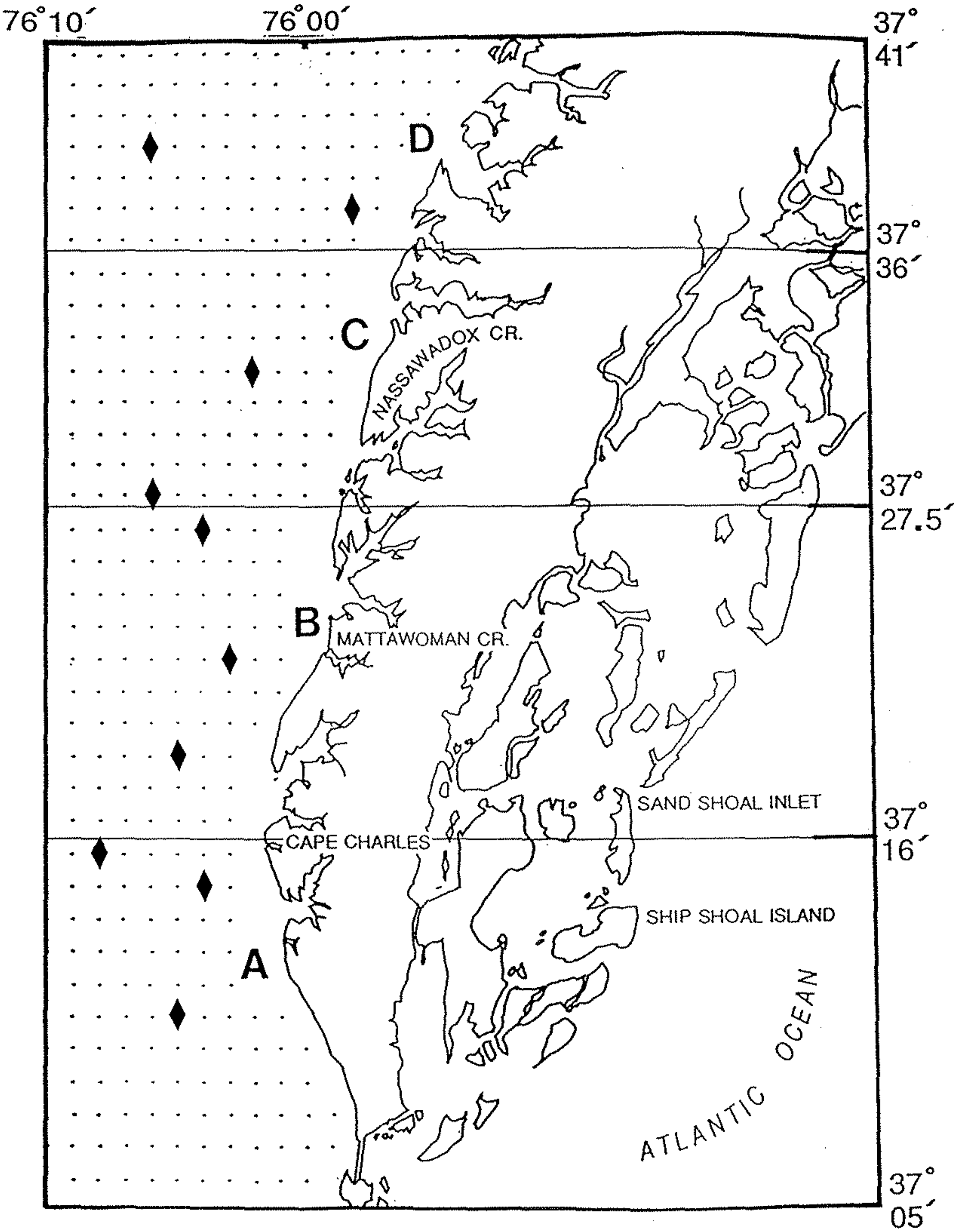

Figure 29. Stations occupied during BD90-04, 1 May 1990, where eggs of black drum were collected.

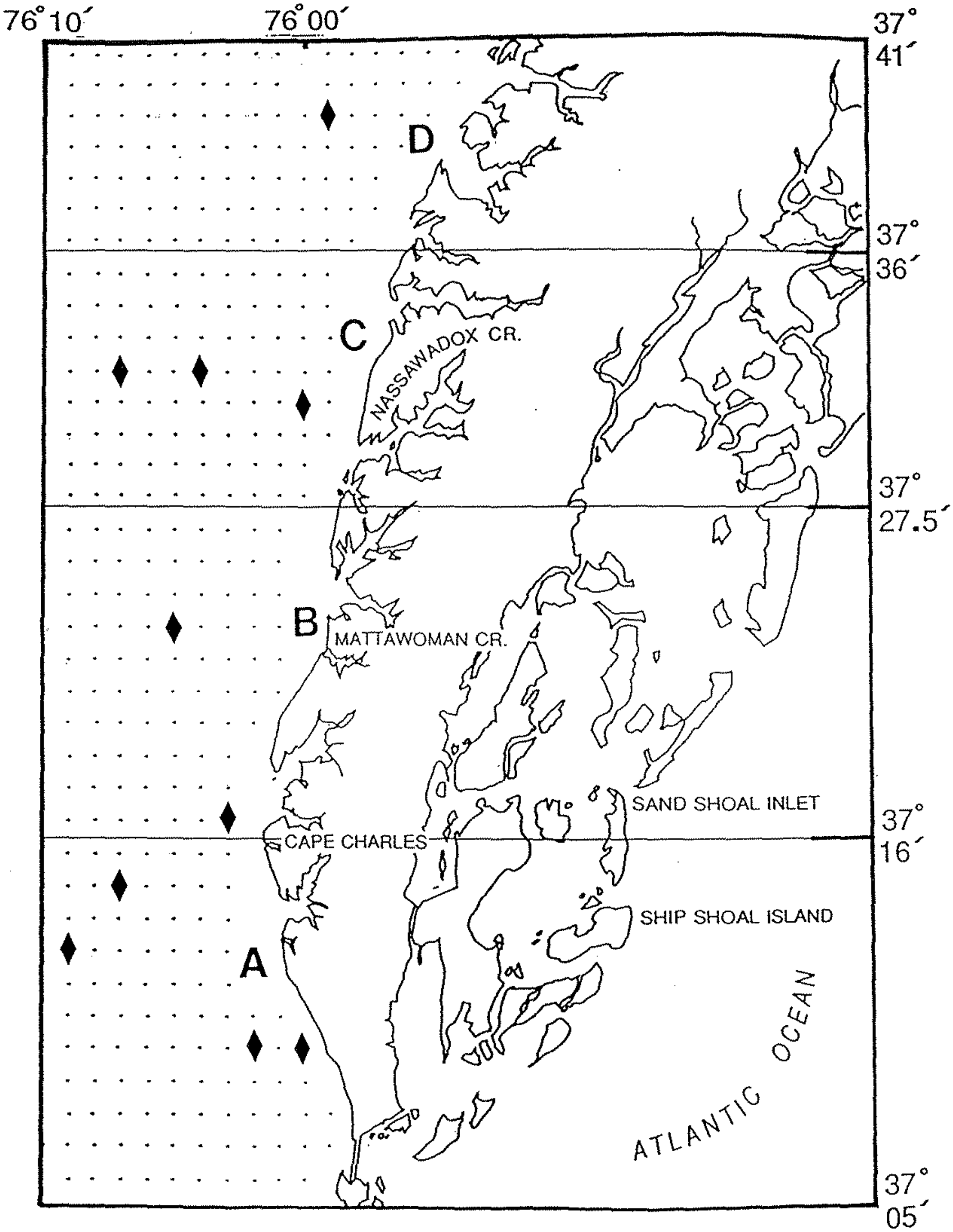

Figure 30. Stations occupied during BD90-05, 8 May 1990, where eggs of black drum were collected.

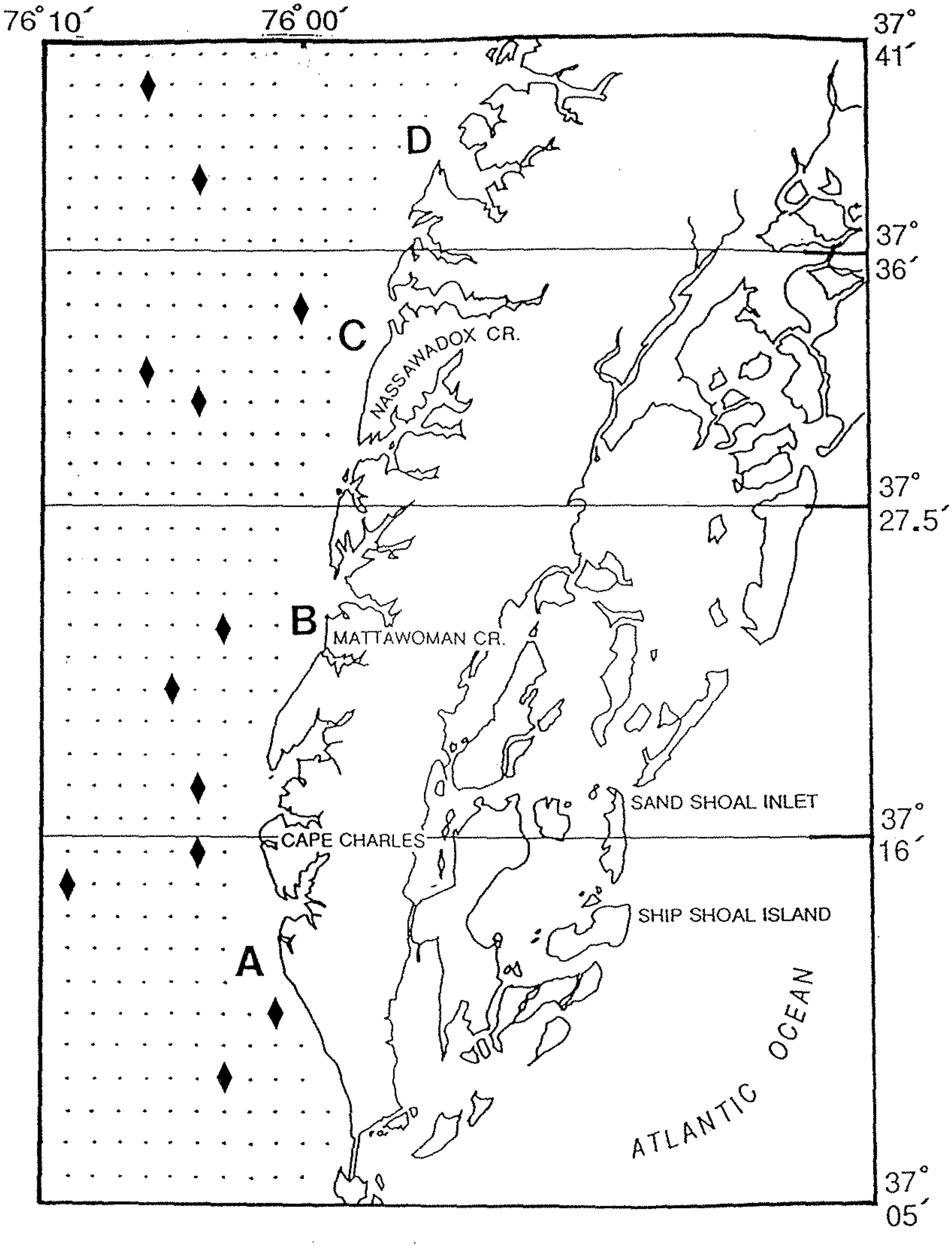

Figure 31. Stations occupied during BD90-06, 15 May 1990, where eggs of black drum were collected.

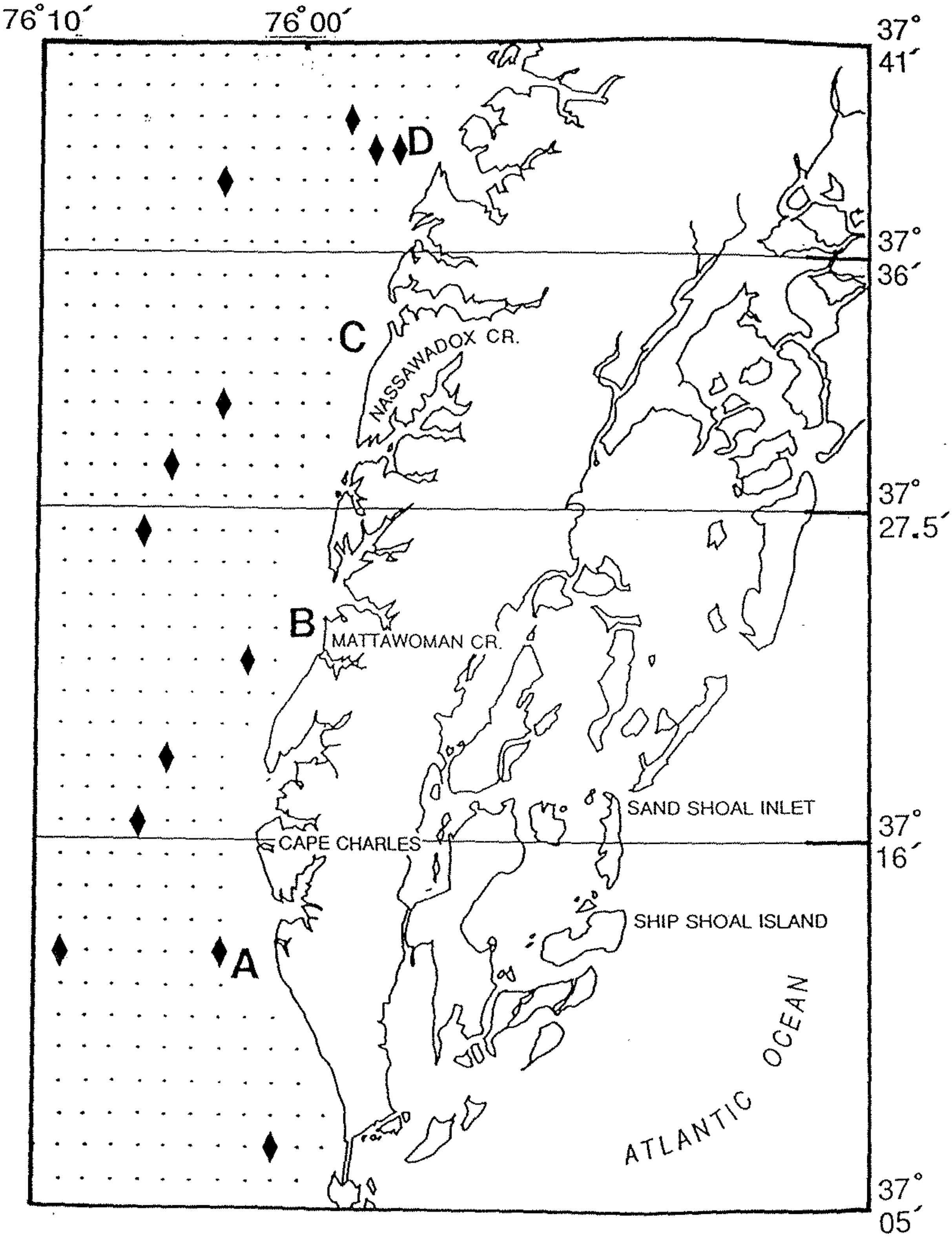

Figure 32. Stations occupied during BD90-08, 25 May 1990, where eggs of black drum were collected.

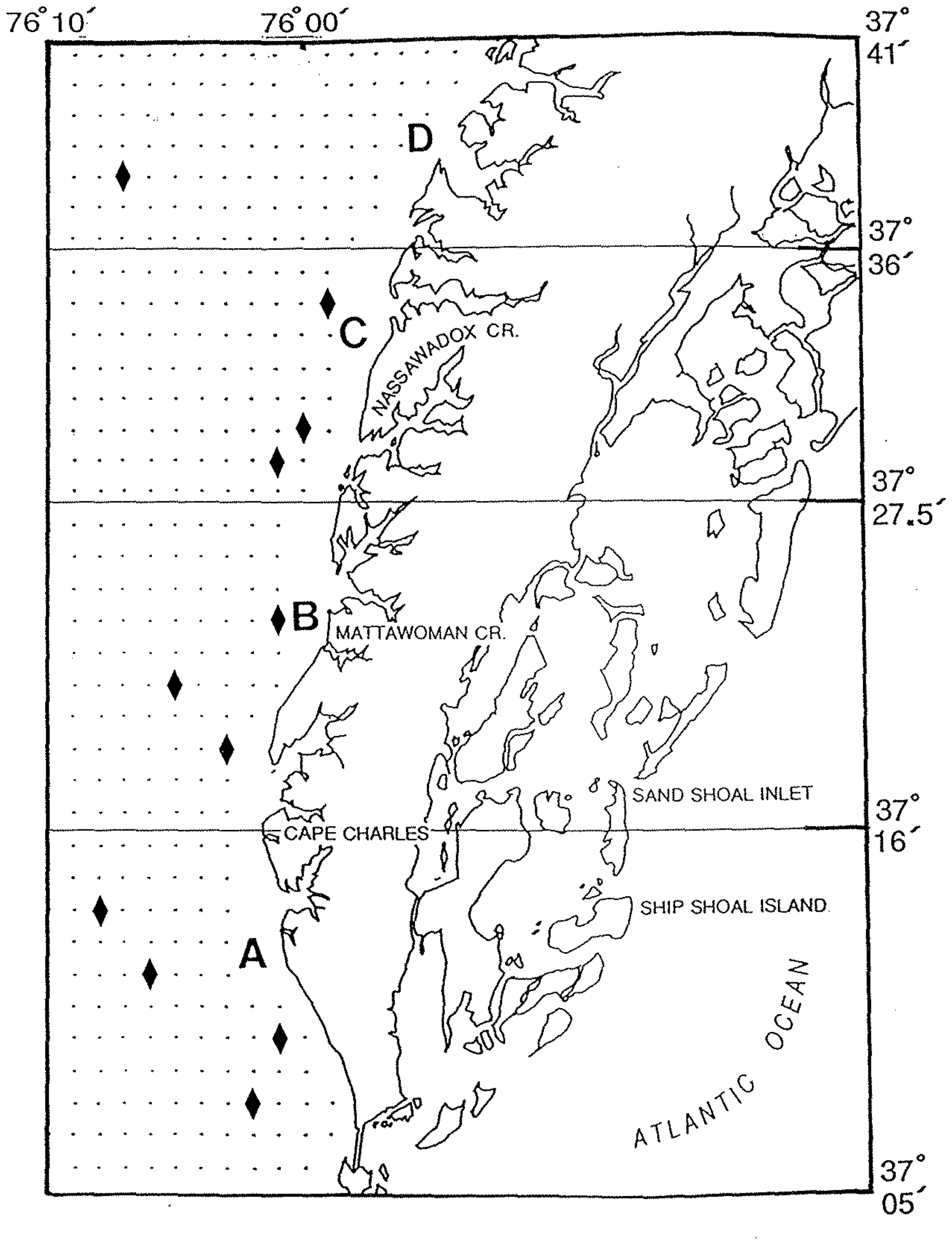

Figure 33. Stations occupied during BD90-09, 1 June 1990, where eggs of black drum were collected.

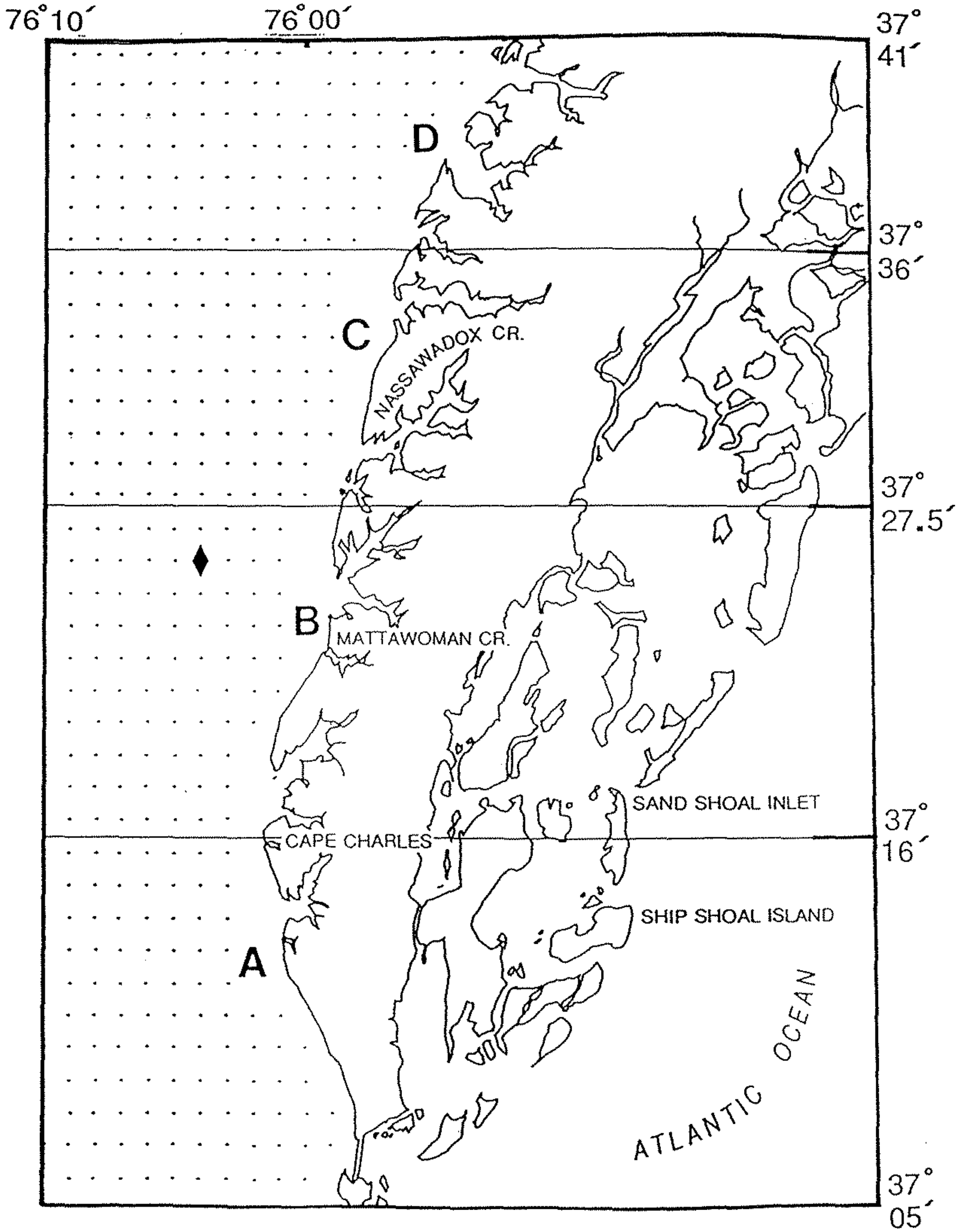

Figure 34. Stations occupied during BD91-04, 22 April 1991, where eggs of black drum were collected.

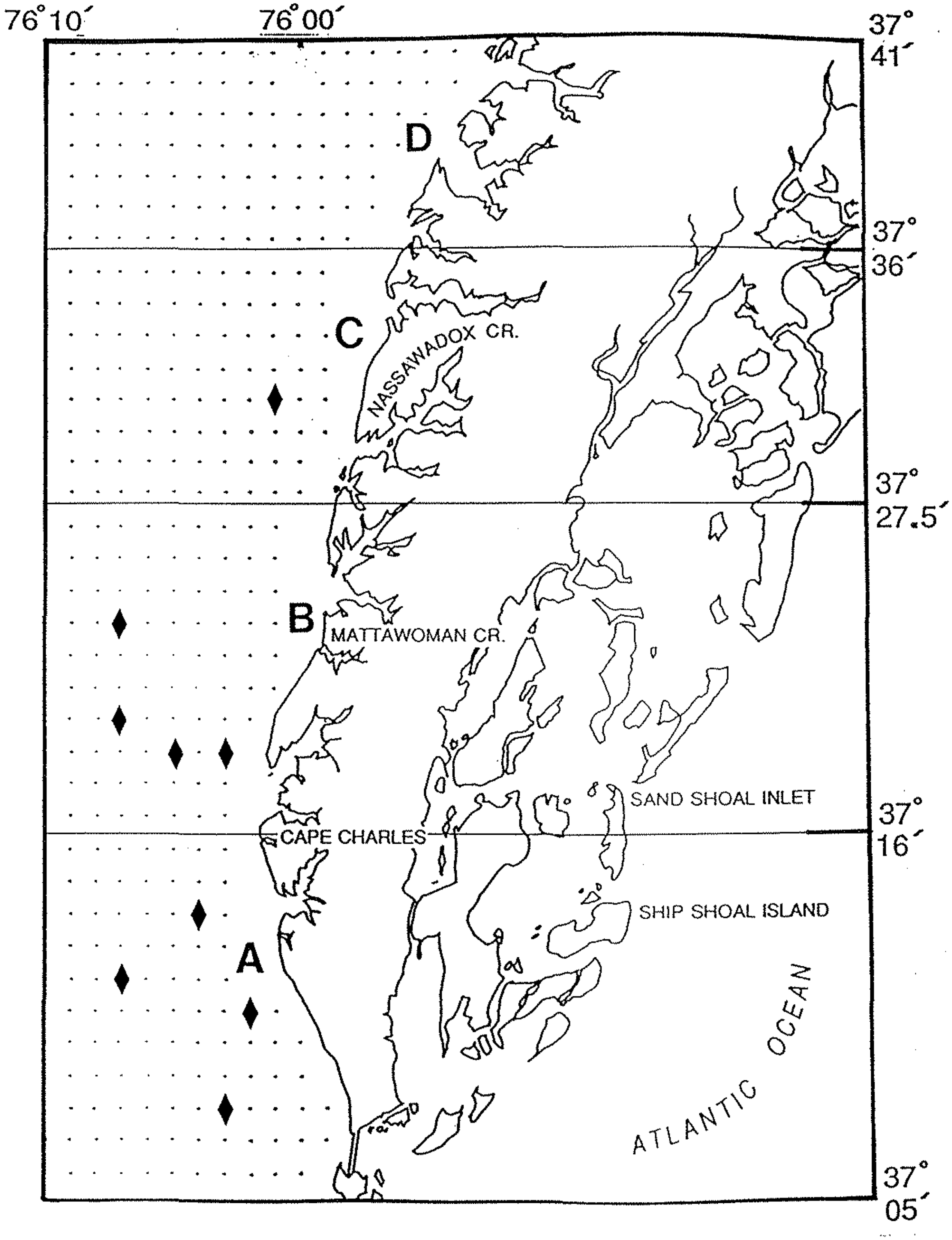

Figure 35. Stations occupied during BD91-05, 29 April 1991, where eggs of black drum were collected.

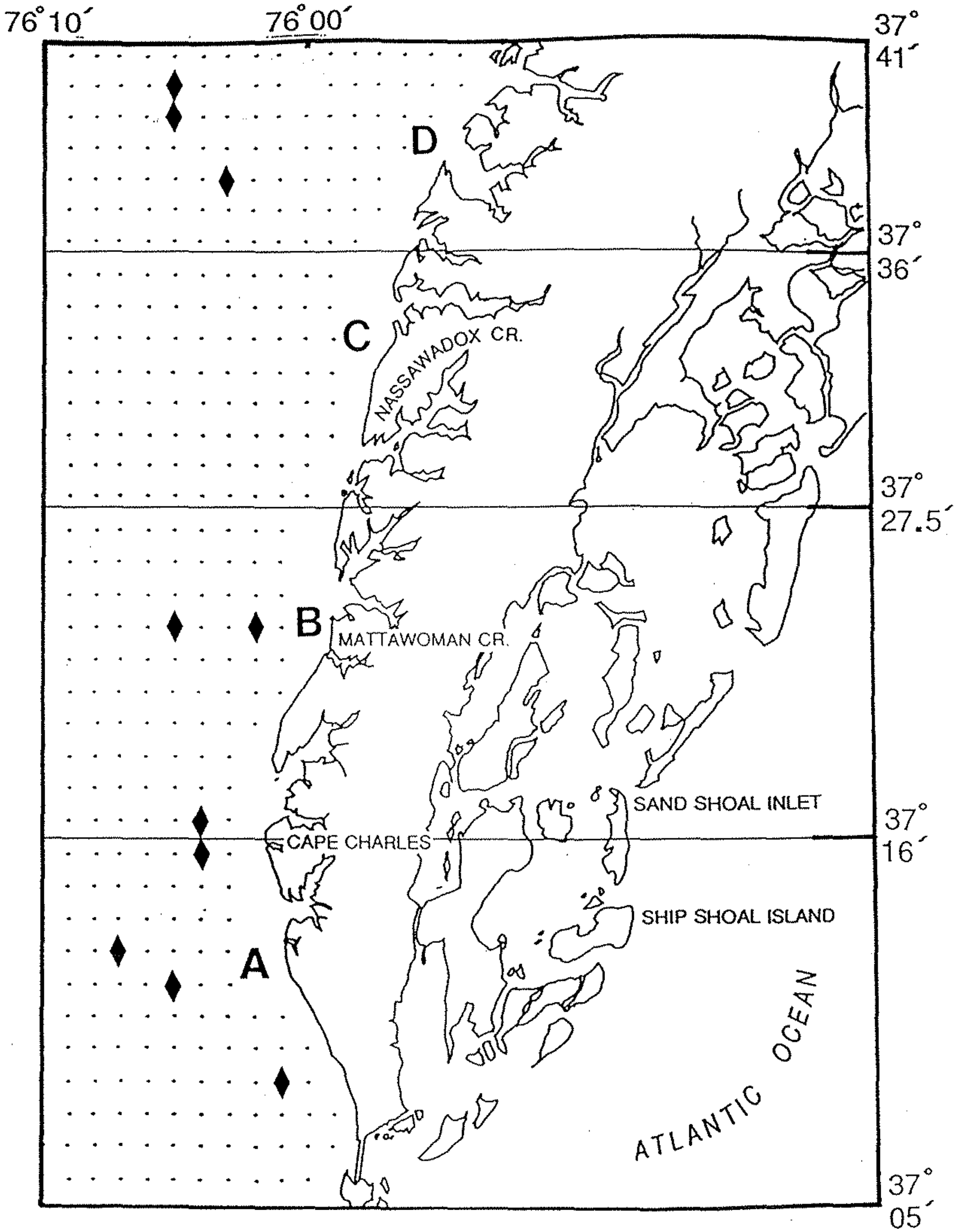

Figure 36. Stations occupied during BD91-06, 9 May 1991, where eggs of black drum were collected.

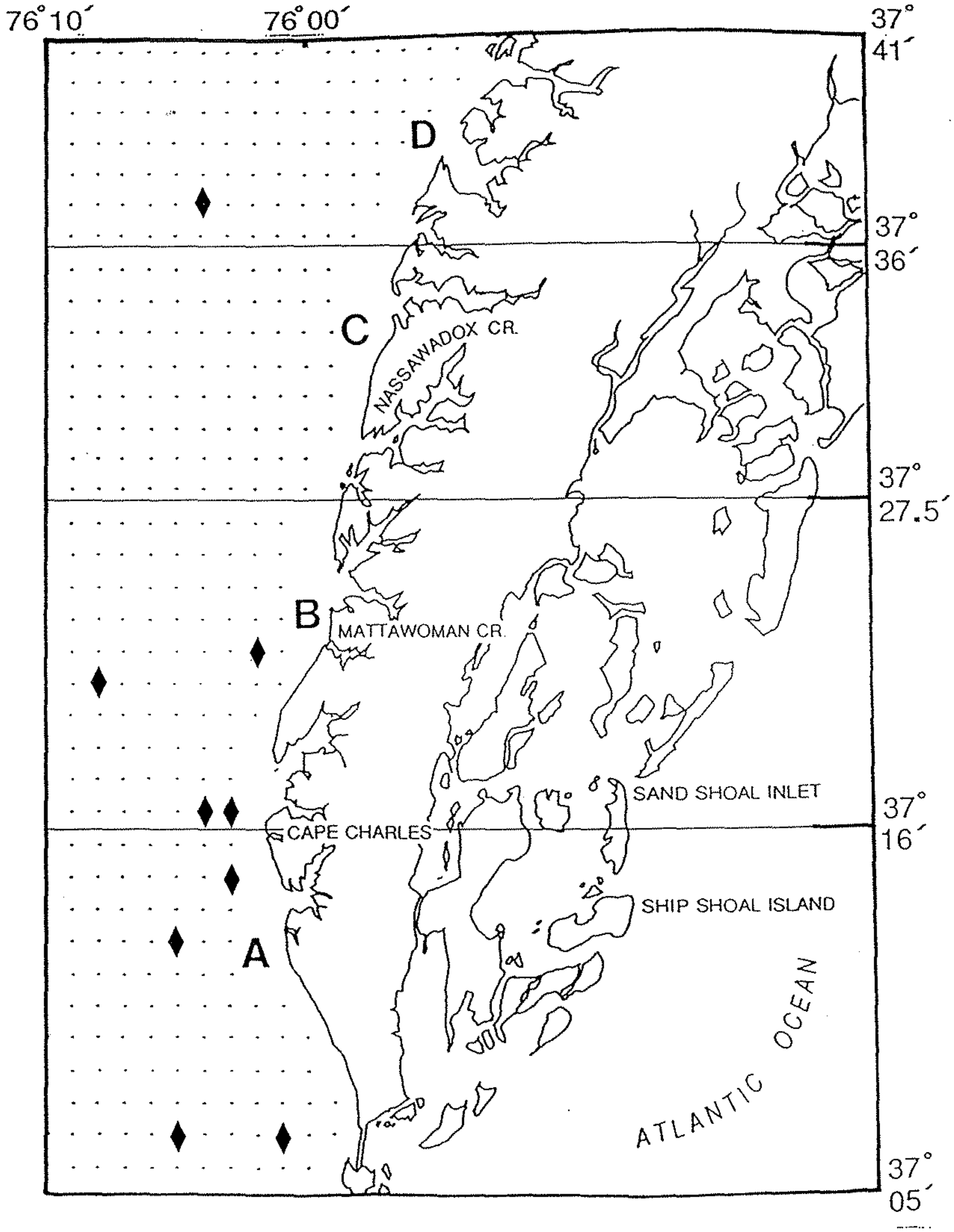

Figure 37. Stations occupied during BD91-07, 15 May 1991, where eggs of black drum were collected.

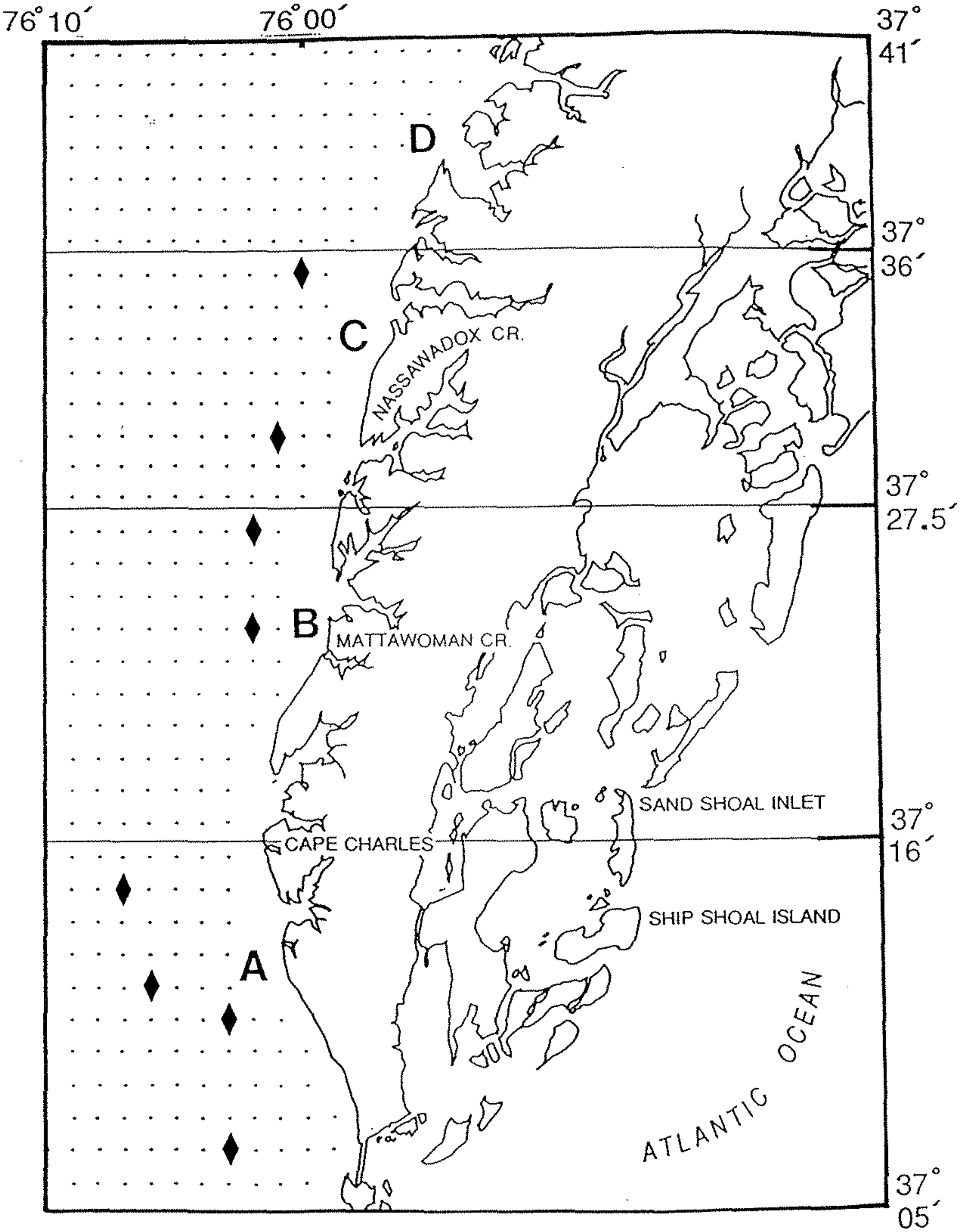

Figure 38. Stations occupied during BD91-09, 22 May 1991, where eggs of black drum were collected.

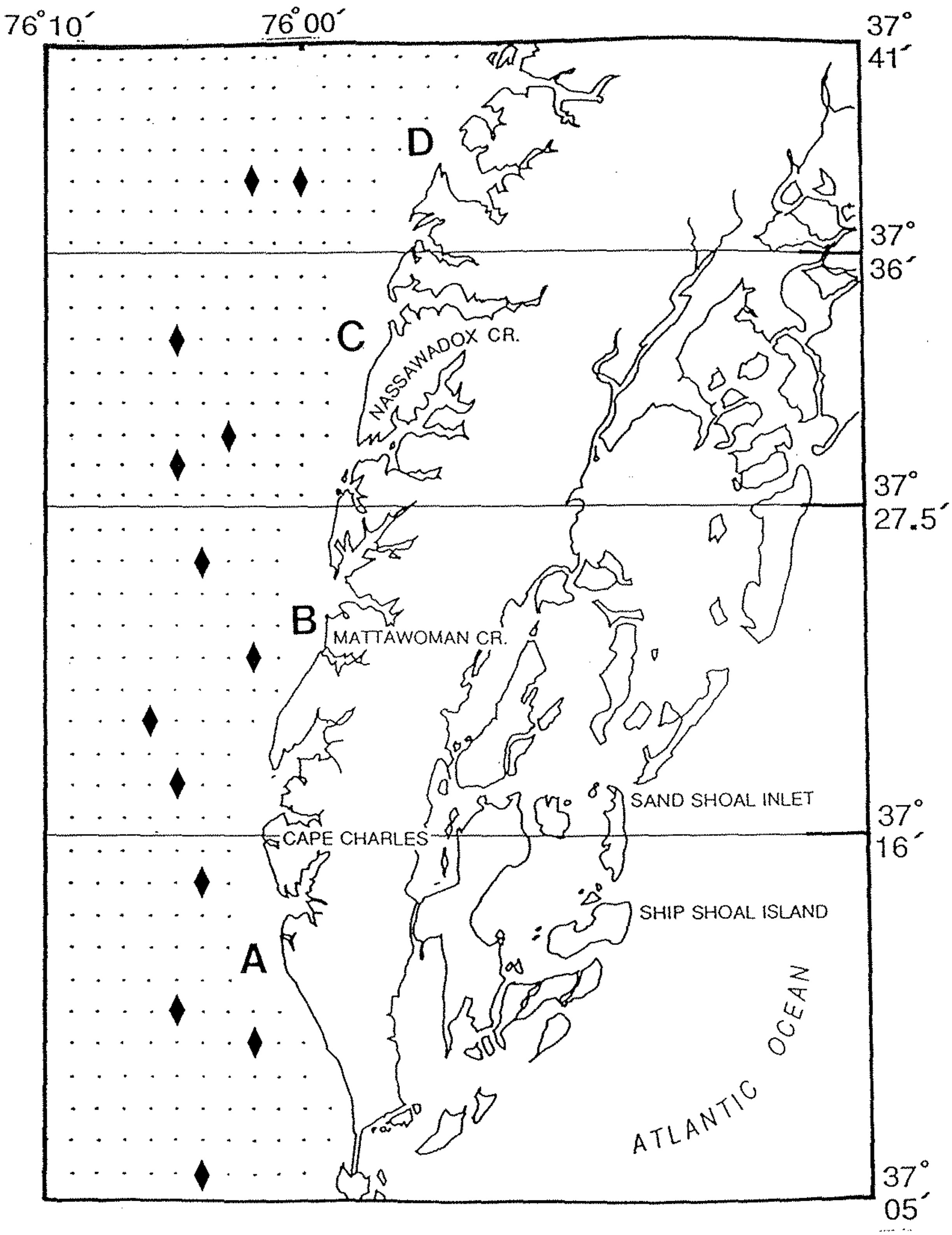

Figure 39. Stations occupied during BD91-10, 29 April 1991, where eggs of black drum were collected.

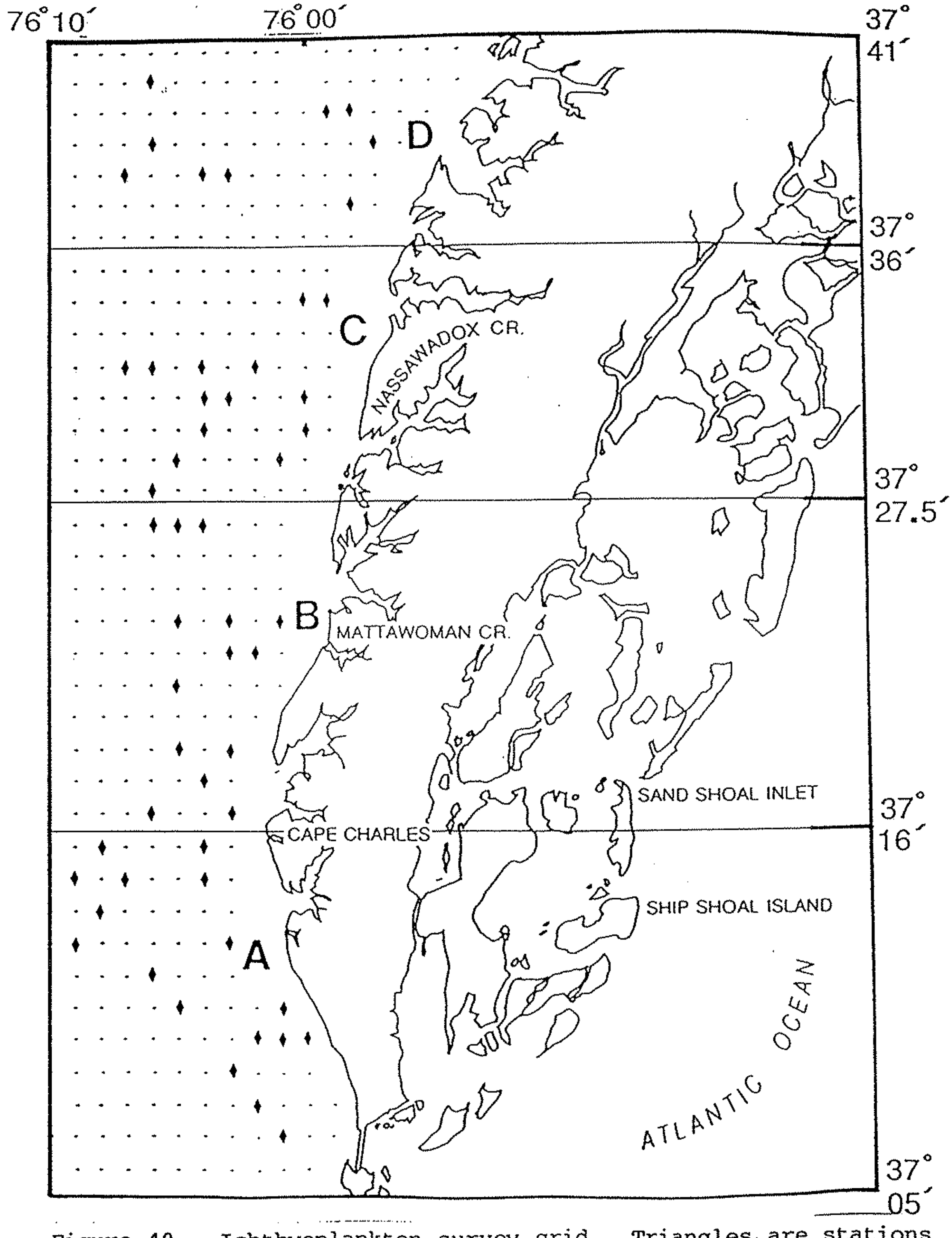

Figure 40. Ichthyoplankton survey grid. Triangles are stations occupied during eight surveys, April - May 1990, where eggs of black drum were collected.

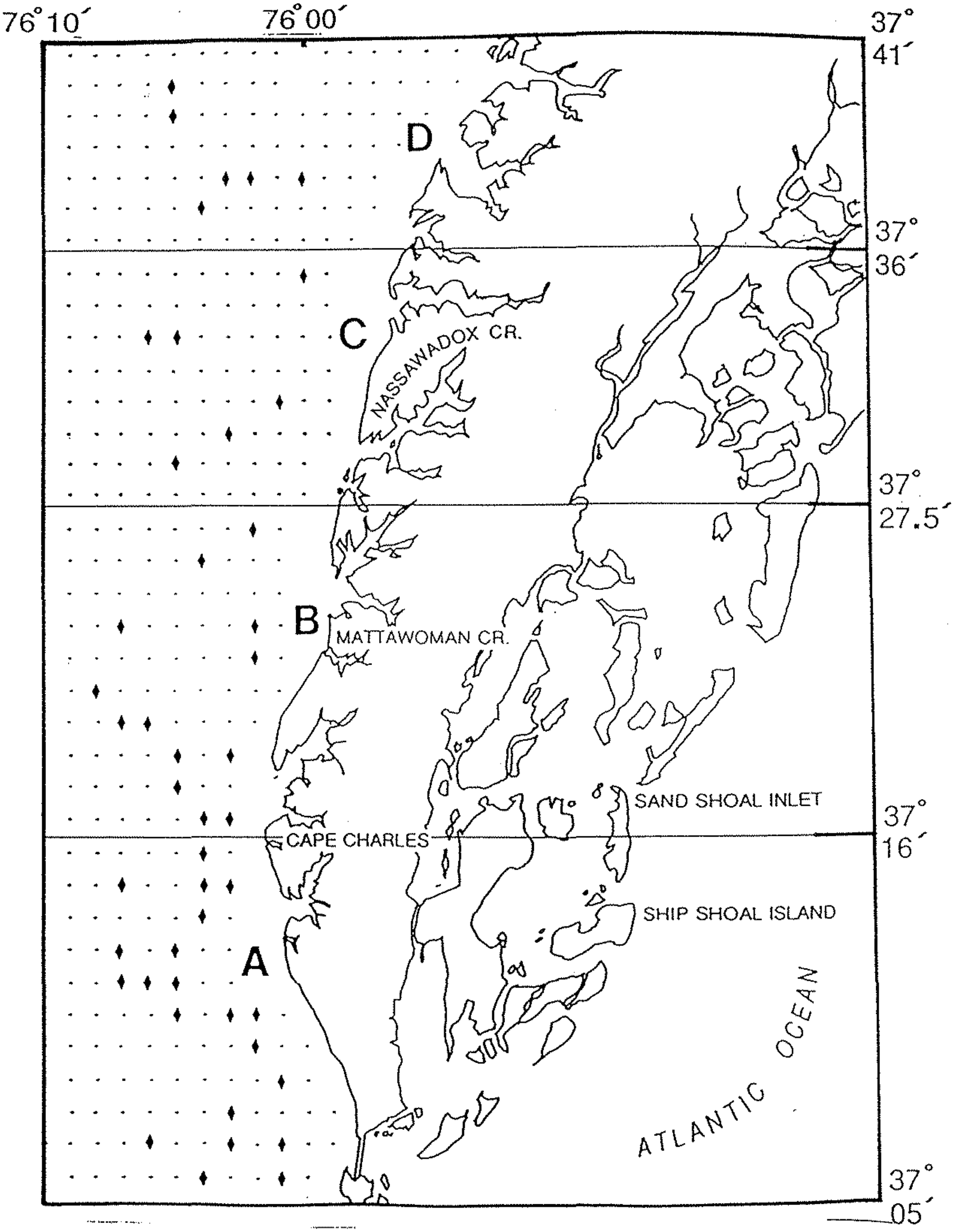

Figure 41. Ichthyoplankton survey grid. Triangles are stations occupied during nine surveys, April - May 1991, where eggs of black drum were collected.

7. Cruise specific estimates of egg production are summarized in Tables 8 and 9. Egg production and biomass estimates based on collections in 1990 ranged from 10 to 25 billion eggs and 64,058 to 161,764 pounds total body weight. In 1991, egg production and biomass estimates ranged from 8.4 to 21 billion eggs and 54,544 to 147,751 pounds. Egg production and biomass estimates resulting from each of three methods as well as a single estimate of annual variance (and associated values) are reported in Table 10.

Table 7. Summary table of raw data used to calculate 1990 seasonal egg production of black drum. Abbreviations are: Sta - station; Z - depth in meters; Vol - volume filtered in m^3; T - temperature in degrees Celsius; and S - salinity in parts per thousand.

Cruise	Date	Time	Sta	Z	Eggs	Vol	T	S
BD90-03	24:IV:90	1230	C61	12	1	64.9	8.5	20.2
BD90-04	1:V:90	0856	A40	7	1	70.5	15.8	20.4
BD90-04	1:V:90	1020	A13	18	145	68.9	16.3	20.8
BD90-04	1:V:90	1100	A2	10	1	59.8	16.4	18.7
BD90-04	1:V:90	1140	B67	14	98	51.2	15.9	21.8
BD90-04	1:V:90	1300	B43	12	6	76.1	16.5	19.4
BD90-04	1:V:90	1416	B6	8	6	77.9	16.2	18.9
BD90-04	1:V:90	1440	C80	10	1	60.2	16.8	16.4
BD90-04	1:V:90	1520	C41	16	1	68.8	16.0	18.8
BD90-04	2:V:90	1330	D51	6	9	80.5	n.d.	n.d.
BD90-04	2:V:90	1441	D87	6	6	68.8	16.3	17.2
BD90-05	8:V:90	0929	A56	8	3	61.7	17.1	18.7
BD90-05	8:V:90	1016	A54	8	2	59.4	17.2	19.2
BD90-05	8:V:90	1110	A22	9	1	72.0	17.1	17.8
BD90-05	8:V:90	1150	A10	12	4	77.7	16.8	19.7
BD90-05	8:V:90	1247	B83	9	20	73.9	17.8	16.3
BD90-05	8:V:90	1410	B32	12	11	76.8	17.3	18.1
BD90-05	8:V:90	1440	B5	18	4	69.1	17.0	19.5
BD90-05	8:V:90	1530	C54	8	8	74.2	17.4	17.0
BD90-05	8:V:90	1602	C39	11	2	79.2	17.3	17.0
BD90-05	8:V:90	1630	C36	8	2	87.3	17.4	16.5
BD90-05	8:V:90	1810	D43	11	1	85.1	17.1	15.4
BD90-06	15:V:90	0924	A61	6	1	52.2	17.6	19.1
BD90-06	15:V:90	1047	A44	8	5	50.2	17.8	19.9

BD90-06	15:V:90	1139	A8	10	2	56.1	17.8	18.9
BD90-06	15:V:90	1211	A6	7	70	63.9	18.3	19.5
BD90-06	15:V:90	1231	B75	12	63	55.4	17.8	19.4
BD90-06	15:V:90	1256	B50	18	92	59.2	17.7	20.4
BD90-06	15:V:90	1319	B34	10	34	53.9	17.9	18.9
BD90-06	15:V:90	1430	C50	12	3	62.4	17.8	n.d.
BD90-06	15:V:90	1447	C37	10	4	60.1	n.d.	n.d.
BD90-06	15:V:90	1520	C21	10	1	51.0	18.1	17.5
BD90-06	15:V:90	1709	D20	10	2	57.1	18.0	17.0
BD90-06	15:V:90	1740	D64	6	2	66.4	18.2	17.7
BD90-08	24:V:90	1725	A22	8	11	84.9	18.4	17.7
BD90-08	24:V:90	1657	A28	12	4	63.2	17.2	22.5
BD90-08	24:V:90	1629	A84	7	9	70.2	17.1	23.3
BD90-08	24:V:90	1538	B4	10	8	59.3	18.4	18.5
BD90-08	24:V:90	1440	B44	11	1	71.0	17.8	22.6
BD90-08	24:V:90	1355	B67	18	4	68.7	17.1	23.5
BD90-08	24:V:90	1330	B80	11	38	87.7	17.7	21.2
BD90-08	24:V:90	1245	C51	16	5	65.9	18.0	20.8
BD90-08	24:V:90	1345	C71	14	1	54.9	18.1	20.2
BD90-08	24:V:90	0900	D62	10	6	66.3	18.3	17.1
BD90-08	24:V:90	0930	D61	10	22	70.6	18.4	16.1
BD90-08	24:V:90	1030	D44	12	31	57.3	18.3	18.1
BD90-08	24:V:90	1455	D68	13	13	60.6	18.4	18.1
BD90-09	31:V:90	1700	A32	9	1	93.8	18.7	18.3
BD90-09	31:V:90	1725	A53	7	1	61.9	18.7	19.9
BD90-09	31:V:90	1630	A16	9	3	66.8	18.8	18.6
BD90-09	31:V:90	1745	A72	7	3	56.2	18.4	19.8
BD90-09	31:V:90	1535	B50	18	1	70.4	18.5	21.1
BD90-09	31:V:90	1510	B36	7	2	51.3	18.7	20.2
BD90-09	31:V:90	1555	B69	9	20	57.1	18.8	19.2

BD90-09	31:V:90	1355	C75	7	13	58.2	18.7	17.8
BD90-09	31:V:90	1305	C22	5	19	42.2	18.5	16.6
BD90-09	31:V:90	1335	C65	8	22	50.3	18.8	18.3
BD90-09	31:V:90	1200	D64	5	10	55.7	18.8	17.2

Table 8. Summary table of raw data used to calculate 1991 seasonal egg production of black drum. Abbreviations are: Sta - station; Z - depth in meters; Vol - volume filtered in m^3; T - temperature in degrees Celsius; and S - salinity in parts per thousand.

Cruise	Date	Time	Sta	Z	Eggs	Vol	T	S
BD91-04	23:IV:91	1020	A96	8	1	60.0	12.6	23.3
BD91-05	29:IV:91	1000	A71	6	64	63.1	14.6	26.8
BD91-05	29:IV:91	1030	A43	10	20	48.3	14.7	22.1
BD91-05	29:IV:91	1100	A31	9	1	42.0	14.6	21.3
BD91-05	29:IV:91	1130	A20	24	8	46.3	14.7	22.4
BD91-05	29:IV:91	1210	B69	9	4	51.5	14.9	20.1
BD91-05	29:IV:91	1300	B67	12	43	67.2	14.8	20.7
BD91-05	29:IV:91	1340	B57	12	25	71.6	15.0	20.5
BD91-05	29:IV:91	1415	B30	10	1	59.1	14.7	19.1
BD91-05	29:IV:91	1825	C53	8	3	56.8	15.2	18.4
BD91-06	10:V:91	1015	A63	5	88	67.1	17.9	23.5
BD91-06	10:V:91	0915	A33	8	2	72.4	17.7	18.8
BD91-06	10:V:91	0850	A24	9	14	82.7	17.6	18.7
BD91-06	10:V:91	0810	A6	6	342	68.5	18.0	17.8
BD91-06	9:V:91	1810	B82	8	4	56.2	18.0	18.0
BD91-06	9:V:91	1700	B35	10	2	71.7	17.5	17.6
BD91-06	9:V:91	1230	D68	13	1	56.2	17.1	17.7
BD91-06	9:V:91	1200	D37	9	6	59.2	17.7	15.5
BD91-06	9:V:91	1130	D21	9	5	56.8	17.8	15.8
BD91-07	15:V:91	0915	A84	5	147	75.0	18.8	15.3
BD91-07	15:V:91	1005	A79	6	1	66.2	19.3	21.9
BD91-07	15:V:91	1105	A26	10	12	91.2	19.1	22.0
BD91-07	15:V:91	1130	A14	3	369	80.8	20.1	21.2
BD91-07	15:V:91	1305	B82	8	188	95.3	19.6	21.9
BD91-07	15:V:91	1350	B83	9	6	72.0	19.3	21.1
BD91-07	15:V:91	1430	B47	9	15	83.1	18.9	20.5
BD91-07	15:V:91	1515	B44	7	39	79.8	20.0	19.8

BD91-07	15:V:91	2030	D76	11	4	87.6	19.0	15.7
BD91-09	22:V:91	1840	A82	6	1	67.3	19.1	25.1
BD91-09	22:V:91	1800	A42	8	2	87.4	19.4	23.1
BD91-09	22:V:91	1720	A32	8	2	78.9	19.4	21.6
BD91-09	22:V:91	1635	A10	12	2	76.0	19.6	21.8
BD91-09	22:V:91	1502	B35	11	2	42.3	19.7	20.9
BD91-09	22:V:91	1445	B8	10	1	74.4	19.8	20.7
BD91-09	22:V:91	1416	C64	8	3	49.3	19.8	20.1
BD91-09	22:V:91	1220	C10	9	1	60.9	19.4	19.1
BD91-10	29:V:91	0750	A92	6	1	49.0	21.9	22.3
BD91-10	29:V:91	0835	A52	9	7	34.2	22.0	21.6
BD91-10	29:V:91	0900	A40	9	3	27.0	22.2	20.9
BD91-10	29:V:91	0932	A13	6	10	20.9	23.1	19.2
BD91-10	29:V:91	0955	B74	8	8	6.2	23.4	18.8
BD91-10	29:V:91	1020	B58	15	6	n.d.	22.3	20.0
BD91-10	29:V:91	1120	B44	9	5	n.d.	22.6	20.0
BD91-10	29:V:91	1200	B15	12	2	19.6	22.3	20.3
BD91-10	28:V:91	1605	C71	12	2	55.5	22.3	19.6
BD91-10	28:V:91	1540	C62	15	2	37.3	22.1	19.7
BD91-10	28:V:91	1515	C27	9	10	45.2	22.9	17.8
BD91-10	28:V:91	1300	D71	8	1	34.5	22.9	17.2
BD91-10	28:V:91	1230	D69	9	2	46.8	23.6	16.0

* n.d. = no data

Table 9. Summary of parameters used in calculations of 1990 egg production of black drum. Abbreviations are; Days - the number of days represented by each cruise;, Density - mean egg density (eggs/m^2) over all positive stations; Method I, Method II and Method III - different cruise specific egg production estimates; Temp - average water column temperature (Celsius) during each specific cruise.

Cruise	Date	Days	Density	Method I	Method II	Method III	Variance	Temp
3	23 April	7.5	0.32	5.45×10^{6}	5.45×10^{6}	5.45×10^{6}	1.20×10^{10}	8.47
4	1 May	7.5	6.77	4.92×10^{9}	5.33×10^{9}	1.1×10^{10}	1.56×10^{19}	16.30
5	8 May	7	1.26	9.19×10^{8}	1.12×10^{9}	2.1×10^{9}	2.88×10^{14}	17.22
6	15 May	8	4.98	2.39×10^{9}	2.60×10^{9}	7.2×10^{9}	4.67×10^{18}	17.88
8	25 May	7.5	2.14	1.56×10^{9}	4.34×10^{9}	3.6×10^{9}	1.38×10^{16}	17.83
9	31 May	3.5	1.16	1.60×10^{8}	7.2×10^{8}	6.8×10^{8}	5.39×10^{14}	18.70

Table 10. Summary of parameters used in calculations of 1990 egg production of black drum. Abbreviations are; Days - the number of days represented by each cruise;, Density - mean egg density (eggs/m^2) over all positive stations; Method I, Method II and Method III - different cruise specific egg production estimates; Temp - average water column temperature (Celsius) during each specific cruise.

Cruise	Date	Days	Density	Method I	Method II	Method III	Variance	Temp.
4	22 April	6.5	0.17	2.5×10^6	2.5×10^6	2.5×10^6	7.2×10^8	12.8
5	29 April	8.5	3.04	1.5×10^9	2.3×10^9	4.0×10^9	6.3×10^{16}	14.7
6	9 May	7.5	6.41	2.2×10^9	2.6×10^9	1.1×10^{10}	2.2×10^{18}	17.7
7	15 May	6	6.38	3.8×10^9	3.8×10^9	4.6×10^9	5.4×10^{17}	19.4
9	22 May	7.5	0.4	1.9×10^8	1.9×10^8	4.4×10^8	1.4×10^{12}	19.5
10	28 May	3.5	2.02	6.8×10^8	8.5×10^8	1.4×10^9	5.7×10^{14}	22.6

Table 11. Data summary for 1990 and 1991 egg production and population biomass estimates of black drum in lower Chesapeake Bay.

YEAR	1990	1991
TOTAL DAYS	41	39.5
MEAN DENSITY	3.35	3.19
TOTAL AREA I	175	150
TOTAL AREA II	400	201
TOTAL AREA III	443	368
TOTAL FECUNDITY	1.67×10^{7}	1.80×10^{7}
EGGS/KILOGRAM	6.8×10^{5}	7.3×10^{5}
METHOD I	9.9×10^{9}	8.4×10^{9}
METHOD II	1.4×10^{10}	9.8×10^{9}
METHOD III	2.5×10^{10}	2.1×10^{10}
METHOD I BIOMASS	64,058 lbs.	50,630 lbs.
METHOD II BIOMASS	90,588 lbs.	59,068 lbs.
METHOD III BIOMASS	161,764 lbs.	126,575 lbs.
TOTAL VARIANCE	2.03×10^{19}	2.80×10^{18}
95% CONFIDENCE INTERVALS	2.21×10^{9}	8.20×10^{8}
COEFFICIENT OF VARIATION	45%	20%

DISCUSSION

Our data concerning the spatio-temporal aspects of spawning of black drum are consistent with the observations of Joseph et al. (1962) who collected eggs of black drum in the Bay, just north of Kiptopeke Beach and in the barrier island inlets. Joseph et al. (1962) did not calculate egg densities for their samples but did report collecting a maximum number of about 2,000 eggs in a 5 minute tow of a slightly larger, 1 m. net. Therefore, spawning intensity is annually variable and may have been greater, at least by a factor of ten, in at least one previous year. Based on the absence of additional published reports of eggs in the plankton, black drum probably do not spawn elsewhere within Chesapeake Bay. The size of the seaside population and the spatio-temporal extent of their spawning activity is presently unknown.

There are no published records of larvae of black drum previously collected in the Bay. Thus, our results confirm that hatching of eggs and survival of larvae to feeding stages does occur naturally in Chesapeake Bay.

Between 1990 and 1991, egg production values declined slightly but confidence intervals overlapped. Calculated values of daily egg production by black drum in Chesapeake Bay (1990, 2.4×10^8 - 6.1×10^8; 1991, 2.1×10^8 - 5.3×10^8) are low when compared to the only other estimate (1.4×10^{10} eggs per day) available for another, closely related species, red drum (Sciaenops ocellatus), in the Gulf of Mexico (Comyns et al., 1990). The methods of Comyns et al. (1990), however, are suspect since the estimates were based on back-calculation of egg densities from larval abundance.

Variance estimates for the two years do not take into account all the possible sources of variability in our samples. Other sources of variability include seasonal changes in egg mortality, daily variability in spawning intensity and weekly variation in the areas of high/low production sites.

JOB 2

Lagrangian time-series analysis of egg distribution and mortality

METHODS

Mortality estimates were estimated from collections containing eggs of black drum that were obtained during two Lagrangian time-series studies. Experiment 1 was initiated on 13 - 14 May 1990, 4.8 miles north-northwest of Cape Charles harbor near buoy C10 (Loran coordinates 27234.4 41559.1). After locating a concentration of fish eggs, the water parcel was marked with 270 L of Rhodamine WT dye dumped at the surface. The dye was tracked visually and samples were made within the dye patch. After 12 h, the dye was becoming undetectable and a single window-shade drogue was deployed just below the surface to track the water parcel for the remainder of the experiment. Replicate sampling (5-min, oblique casts) with the plankton camera was conducted within the dye patch or adjacent to the drogue at 3-h intervals over a complete tidal cycle.

The 1991 time-series experiment began 2.5 miles west of Cape Charles on 23 - 24 May. Methods were similar to those employed in 1990, except that three window shade drogues were set at varying depths (1,3 and 5 m) and followed throughout the 24-h period in 1991.

Eggs of black drum sorted from each replicate preserved sample were staged, using a modified version of the criteria described by Moser and Ahlstrom (1985) (Table 10), to examine decline in specific cohort abundance over time. Time of occurrence of newly fertilized (Stage I) eggs was determined for each preserved sample to estimate diel periodicity of spawning.

Values of instantaneous daily mortality during the 24 h study were estimated from declines in the stage specific densities of a single cohort by using Equation 8:

$$N_t = N_o e^{-zt}$$

Where:

Table 12. Criteria for staging field collected, preserved eggs, modified from Moser and Ahlstrom (1985).

Stage I = Newly fertilized egg, cell division has not begun.

Stage II = Gastrula stage, early cell development.

Stage III = Early embryo visible as a streak, notochord becomes visible and there is differentiation of the optic vesicles from the brain.

Stage IV = Tip of the tail becomes free from yolk and is broadly rounded.

Stage V = Free tail length is less than one-half the yolk-sac length.

Stage VI = Free tail length exceeds one-half yolk-sac length.

N_t = stage specific cohort abundance after 24 h,

N_o= initial stage-specific cohort abundance,

z = instantaneous coefficient of mortality,

t= 1 day.

RESULTS

In 1990, the experiment commenced at 1000 hours, just prior to the predicted time of slack before ebb. The study terminated 21 minutes after slack before ebb on the following day. Tracking of the water parcel during the 24-h period indicated the net transport during ebb tide and the following flood was approximately 15.8 km (Figure 42). The maximum distance between any two stations was 5.4 km, and occurred from Time 0 to Time 3 during maximum ebb (predicted maximum tidal velocity = 1.0 knot). During the last three stations, drogue movement was minimal, partially due to strong easterly winds that commenced early on the morning of 14 May 1990.

In 1991, the first sample was taken at 0715, approximately 1 h prior predicted time of slack before ebb. Experiment 2 terminated at 0820, 24 May 1991, just over 3.5 h after slack before ebb. Tracking of the water parcel over the 24-h period resulted in transport paths similar to those observed in 1990 (Figure 43). Predicted maximum current velocities were greater in 1991, however, and may have accounted for the greater distance travelled during the 1991 experiment (28.4 km). The maximum distance travelled between any two stations was 6.7 km and occurred during the predicted maximum flood current (1.3 knots) between Time 6 and Time 9.

Average water column temperatures during the two years were very similar (Tables 11, 12). Average water column temperatures ranged from 18.3 to 20.0°C in 1990 and from 18.0 to 19.9°C in 1991. Salinities during both years, however, differed markedly. In 1990, salinities ranged from 14.9 to 18.8 $^{\circ}/_{\circ\circ}$ while 1991 values ranged from 18.7 to 26.4 $^{\circ}/_{\circ\circ}$.

Eight replicate samples in 1990 and nine replicates in 1991, all contained eggs of black drum (1990 = 1,266; 1991 = 160). Densities of eggs in 1990 ranged from 5.4 to 466.7 eggs/100m^3 and from 9.4 to 54.1 eggs/100m^3 in 1991. The occurrence of early staged (Stage I and II) eggs was most common from dawn to noon (0715 - 1111 hours) (Table 13). In 1990, recently spawned, stage I, eggs occurred when water column temperature was 19.8 and

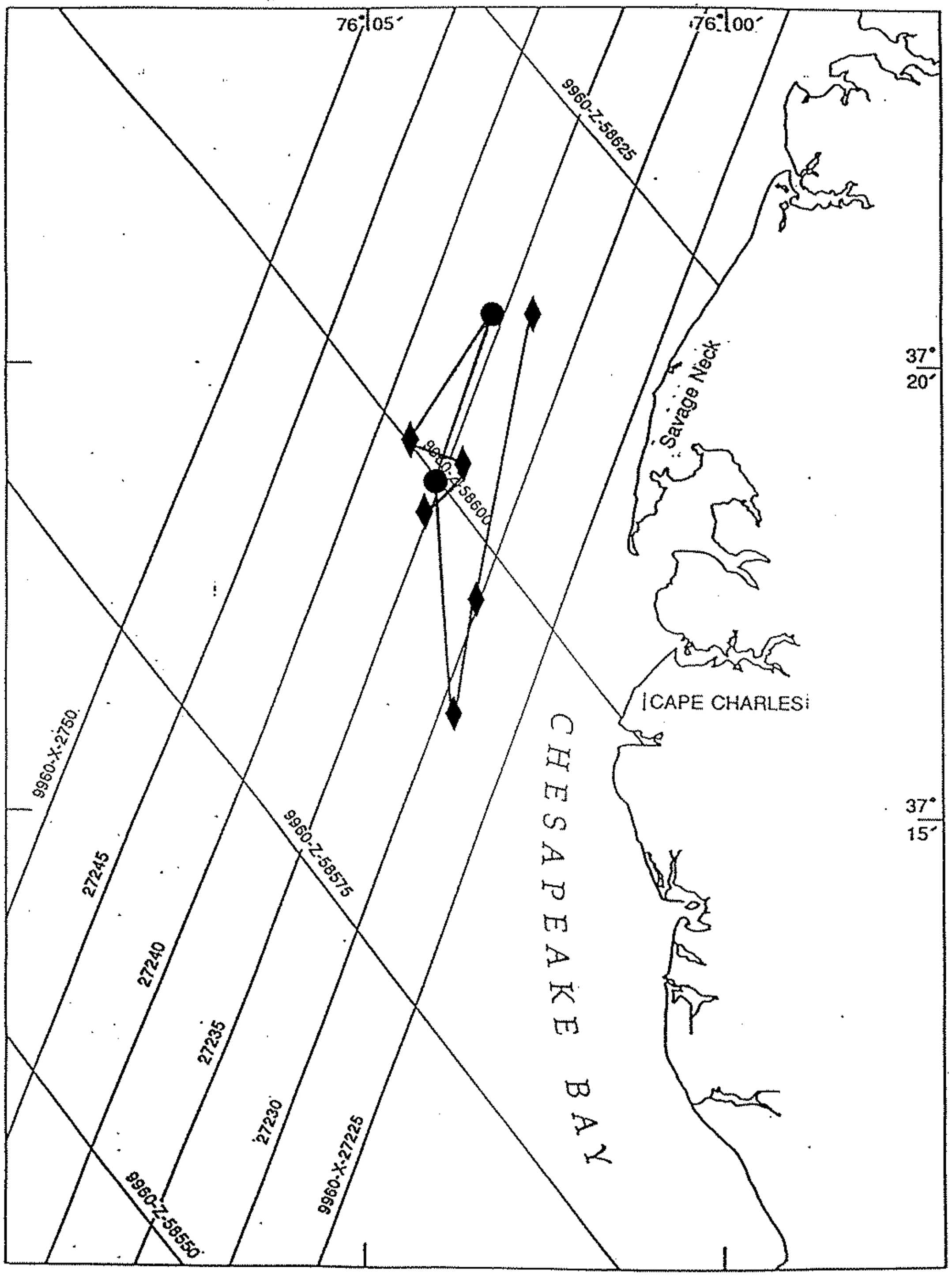

Figure 42. Dye patch and drogue positions recorded during the time-series experiment on 13 and 14 May 1990. Diamonds = stations sampled during ebb; Circles = stations sampled during flood.

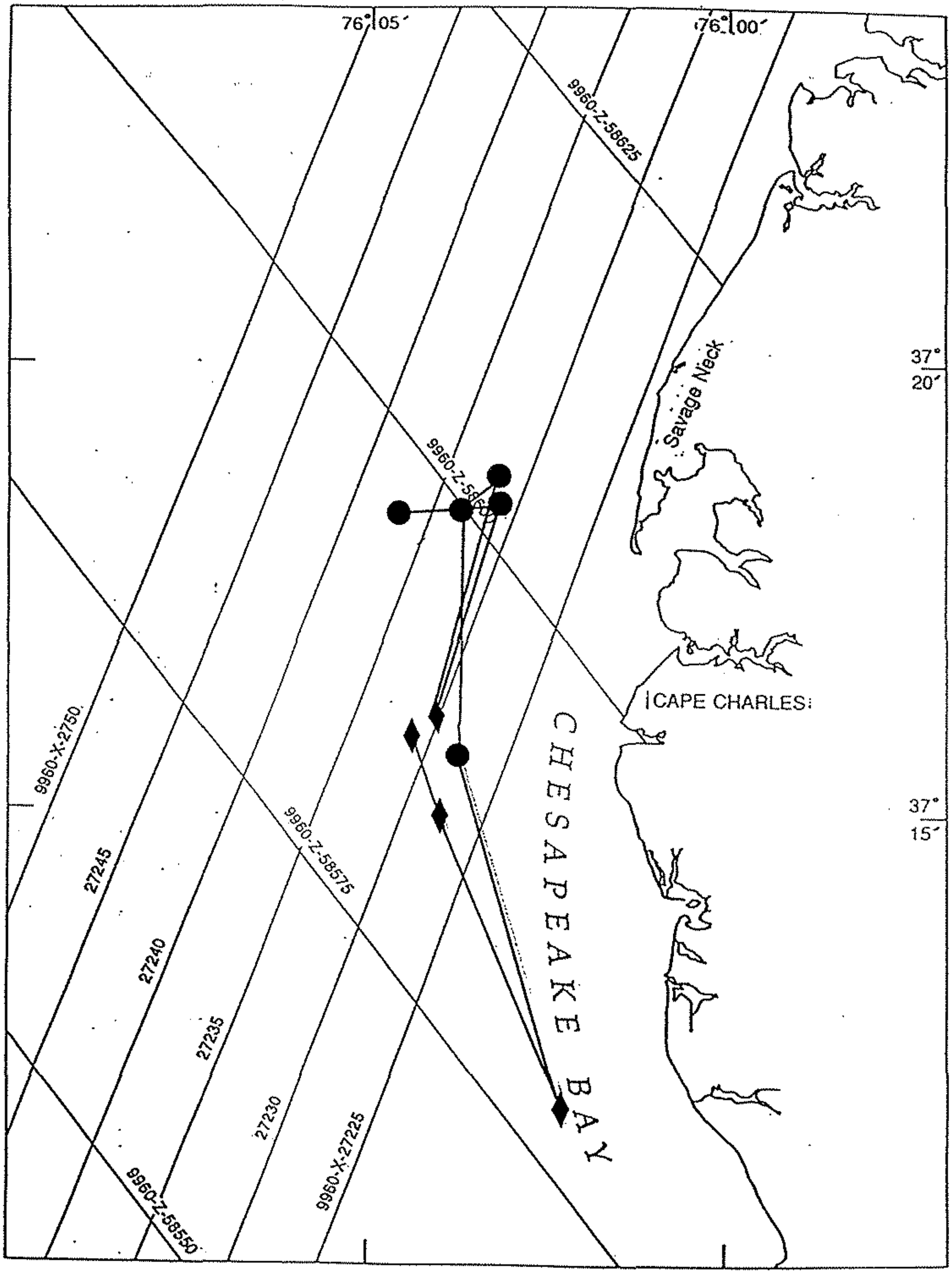

Figure 43. Drogue positions recorded during the time-series experiment on 23 and 24 May 1991. Diamonds = stations sampled during ebb; Circles = stations sampled during flood.

salinity was 17.0. In 1991, stage I eggs occurred when water column temperatures ranged from 18.0 to 19.3°C and salinities ranged from 21.1 to 25.2 $^{\circ}/_{\circ\circ}$. Although a few newly fertilized eggs appeared in collections at other times, Stage I eggs appeared most commonly from 0054 to 0500 hours, suggesting that spawning occurred during predawn and early morning hours. The numbers of eggs staged during each replicate for both 1990 (Table 14) and 1991 (Table 15) reveal that over the 24 h. experiment, 3 cohorts could be identified. The cohort that could be followed throughout the 24 hours was used to determine instantaneous mortality (Table 16, Table 17).

Twenty percent of the eggs of black drum collected during the 1990 experiment were classified as dead (range 8 to 66%). Dead eggs from samples from the 1991 experiment comprised only 8% (range 0 to 13%) of the total. Hatching experiments conducted aperiodically throughout the 1990 and 1991 spawning seasons revealed similar results, however, percentages of dead or inviable eggs were never greater than 33%.

Densities of eggs during the 1990 experiment increased from 1313 hours (Time 3) to 2226 (Time 12) (Table 16), a departure from the expected, steady decline of eggs over time. Since the greatest abundance of eggs occurred at Time 12 (405.24 eggs/100m^3), the estimate of mortality for 1990 was calculated based on the decline from Time 12 to Time 24. The decline in abundance from Time 12 to Time 24 corresponded to an individual cohort mortality rate of 60% d^{-1}. Results from the 1991 experiment showed the expected decline in mean abundance throughout the experiment (Table 17). Mortality estimates calculated from the 1991 experiment were 72% d^{-1}.

Table 13. Time, location (Loran coordinates), temperature (C) and salinity (°/$_{\infty}$) for samples taken during the 1990 time-series experiment.

Collection	Time	Location		C	°/$_{\infty}$
Time 0	1000	27234.4	41559.1	19.4	15.5
Time 3	1313	27231.2	41520.0	20.0	14.9
Time 6	1615	27229.1	41503.9	19.4	18.2
Time 9	1925	27235.1	41534.9	19.4	18.8
Time 12	2226	27236.4	41557.9	19.4	17.7
Time 15	0054	27235.9	41538.1	19.8	17.0
Time 21	0739	27234.5	41534.4	19.7	16.1
Time 24	1111	27234.9	41530.0	18.3	17.1

Table 14. Time, location (Loran coordinates), temperature (C) and salinity (°/$_{oo}$) for samples taken during the 1991 time-series experiment.

Collection	Time	Location	C	°/$_{oo}$
Time 0	0715	27231.1 41500.6	18.0	25.2
Time 3	1030	27228.0 41490.6	18.3	25.0
Time 6	1350	27215.0 41454.2	18.4	26.4
Time 9	1645	27228.7 41498.6	19.0	24.6
Time 12	2000	27233.4 41528.8	19.4	23.9
Time 15	2300	27233.0 41533.8	19.4	22.2
Time 18	0200	27229.3 41500.3	19.9	18.7
Time 21	0500	27232.2 41529.6	19.3	21.5
Time 24	0820	27237.5 41529.6	19.3	21.1

Table 15. Time of occurrence of early stage (I and II) eggs of black drum, combined for both 1990 and 1991 Lagrangian time-series experiments.

Time	Stage I	Stage II	Total	% of Total
Night A.M.	51	2	53	15%
Day A.M.	10	257	267	74%
Night P.M.	0	38	38	10%
Day P.M.	2	3	5	1%

Table 16. Raw counts of eggs of black drum collected during the 1990 time- series experiment by time of collection, developmental stage (I - VI), Number dead and total.

Time	I	II	III	IV	V	VI	dead	total
1000	0	47	0	1	1	2	100	151
1313	2	0	1	0	1	3	1	8
1615	0	1	54	2	3	0	7	67
1925	0	0	155	2	1	4	15	177
2226	0	37	7	237	0	3	31	315
0054	38	0	0	92	0	0	11	141
0739	0	73	0	0	56	15	14	158
1111	0	90	0	0	13	83	77	263

Table 17. Raw counts of eggs of black drum collected during the 1991 time-series experiment by time of collection, developmental stage (I - VI), number dead and total.

Time	I	II	III	IV	V	VI	dead	total
0715	9	11	0	1	16	0	3	40
1030	0	23	0	0	6	0	4	33
1350	0	2	25	1	0	5	5	38
1645	0	0	4	4	2	0	1	11
2000	0	0	0	4	0	2	0	6
2300	0	1	0	3	1	0	0	5
0200	0	1	0	2	4	0	0	7
0500	13	1	0	5	2	0	0	21
0820	1	13	0	0	7	1	1	23

Table 18. Densities (eggs/100m^3) of eggs in 1990 cohort used to calculate the estimate of instantaneous daily mortality. Mortality rates were calculated from the sum of the densities of each cohort (Total).

Time	I	II	III	IV	V	VI	Total
1000	0	91.78	0	0	0	0	91.78
1313	3.57	0	1.79	0	0	0	5.36
1615	0	2.07	111.91	4.14	0	0	118.12
1925	0	0	220.31	2.84	1.42	0	224.57
2226	0	0	11.62	393.62	0	0	405.24
0054	0	0	0	113.61	0	0	113.61
0739	0	0	0	0	99.23	26.58	125.81
1111	0	0	0	0	25.29	161.45	186.74

Table 19. Densities (eggs/100m^3) of eggs in 1991 cohort used to calculate the estimate of instantaneous daily mortality. Mortality rates were calculated from the sum of the densities of each cohort (Total).

Time	I	II	III	IV	V	VI	Total
0715	15.25	18.64	0	0	0	0	33.89
1030	0	54.07	0	0	0	0	54.07
1350	0	2.92	36.46	1.46	0	0	40.84
1645	0	0	6.97	6.97	3.49	0	17.43
2000	0	0	0	6.50	0	0	6.50
2300	0	0	0	5.64	1.88	0	7.52
0200	0	0	0	3.23	6.45	0	9.68
0500	0	0	0	7.50	3.00	0	10.50
0820	0	0	0	0	13.10	1.87	14.97

DISCUSSION

Results from the two Lagrangian time-series experiments indicated that black drum spawn during early morning and pre-dawn hours from 0054 to 0500 hours (Stage I eggs). The occurrence of all early stage (I and II) eggs was most common from 0715 to 1111. These findings inexplicably differ from Holt et al. (1985) who found black drum to spawn at dusk (1700 - 1900) in the Gulf of Mexico. Since the equation for the calculation of instantaneous daily mortality requires the calculation of the time between spawning and sample collection, imprecise assignment of the time of spawning may result in higher estimates of initial abundance and mortality. For the purposes of calculation of initial abundance of black drum eggs in our egg production models (Job 1), we used midnight as a conservative estimate of time of spawning.

The average percentage of dead eggs (8 and 20%) in our samples was lower than those reported by Cowan et al. (1991). Cowan et al. (1991) reported that 50% of the eggs used in their mesocosm experiments were dead, however, they attribute this higher value to the handling procedures necessary in correctly stocking their enclosures.

The drogue and/or dye positions marked during the experiment suggested that a water parcel in the study area maintained its identity over a tidal cycle, possibly minimizing losses due to expatriation. However, the influx of eggs into the 1990 samples tend to refute this hypothesis. Greater knowledge of the hydrography of the sample area and increased sophistication in our ability to follow the water parcels would have minimized this problem. Assuming minimal losses to expatriation, our estimates probably reflect losses primarily due to predation and/or cytological mortality.

The values of instantaneous daily mortality calculated from the 1990 (60%/d) and 1991 (72%/d) experiments are very similar to the average mortality estimate determined by Cowan et al. (1991) who examined black drum mortality in mesocosms (70%/d). Therefore, since the

1991 experiment followed the expected mean decline in egg abundance over time, we used a mean value of 70%/d in our calculations for egg production.

JOB TITLE 3

Juvenile nursery habitat, age and growth

METHODS

Sampling for post-larval and juvenile black drum was conducted from June to November, 1989; April to November, 1990 and April to October, 1991. Sites for bi-weekly rotenone, seine and trawl stations were located at Wachapreague Inlet, Quinby Inlet, Cape Charles, Goodwin Island and the Poropotank River. Sites were chosen based on their hydrographic and sedimentological similarity with previously described black drum nursery habitat in Delaware Bay, South Carolina and the Gulf of Mexico.

Rotenone collections were made by blocking a 30 meter section of creek with 1 mm mesh block nets about one hour before the predicted time of low tide. After the nets were secured, rotenone (5% Fish Tox, Woolfolk Chemical Works, Fort Valley, Georgia) was added to the water at the upstream net and carried through the site with the ebbing tidal currents. The amount of rotenone used at each site varied due to the width and depth of the creek, but on the average, 175 ml was sufficient for a good sample. At the downstream net, potassium permanganate ($KMnO_4$) was added to the water exiting the site to oxidize the rotenone and minimize any extra-site mortality. Affected fishes in the enclosed area were dipnetted at the surface, and after no further surface activity was detected, the site was seined with a 5 m bag seine with 4 mm bar mesh. The lower net was then pulled and fishes swept downstream were removed. The entire catch was then preserved in 10% seawater buffered Formalin and returned to the laboratory. For trawl samples, a small, 16 foot semi-balloon otter trawl was employed in the seagrass (<u>Zostera marina</u> and <u>Ruppia maritima</u>) meadows at Cape Charles and those bordering rotenone sites. Trawls were limited to depths < 4 meters. Four to 8 stations were occupied at each location and all fishes were quickly identified, measured (SL mm) and released. Seine (10 m; 4 mm mesh) and gill net (50 m; 5.6 cm. mesh) collections were made in the York River and in bayside and seaside eastern shore creeks (Nandua, Inlet, Onnancock, Cherrystone, Hungars, Assowoman, Parramore, Wachapreague) (Figure 38).

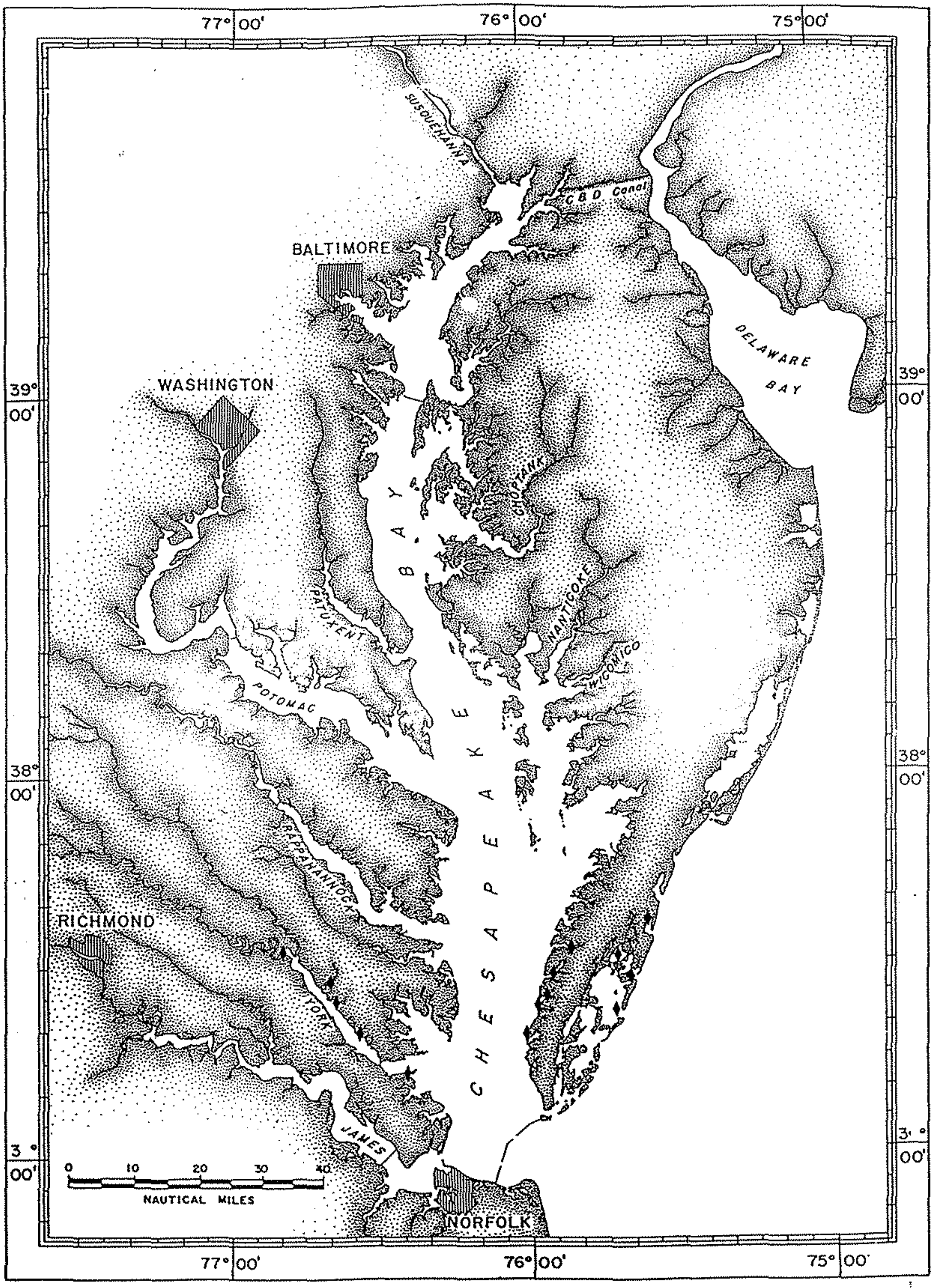

Figure 44. Ichthyofauna survey stations. Diamonds represent stations occupied during the juvenile habitat survey, June 1989 - October 1991.

RESULTS

During the three sampling periods from 1989 through 1991, over 500 samples resulted in the collection of 70 species of fishes (Tables 17, 18), some considered rare or uncommon for Chesapeake Bay. The sampled habitats ranged from soft mud to grass with salinities ranging from 0 to 33 p.p.t. and temperatures from 15 to 31°C. During the entire survey, however, only 13 young of the year black drum (138 - 194 mm SL) were collected (Table 19). The specimens obtained were collected in the fall (September and October) in a bayside (Nandua) and seaside (Assowoman) eastern shore creek using small (5.6 cm) mesh gill nets and up the York River in winter using trawls. Infrequent reports of young of the year being collected either by commercial or recreational fishing gear were investigated, however, no specimens ever resulted from this effort.

Table 20. Checklist of fishes (by site) collected in the juvenile nursery habitat study, using rotenone, seines, trawls and gill nets from June 1989 through October 1991. Temperature and salinity ranges are in parentheses after each site.

SITE LOCATION:

POROPOTANK RIVER: (15 - 31 C), (3 - 11 p.p.t.)

Anchoa mitchilli	Leiostomus xanthurus
Anguilla rostrata	Menidia menidia
Bairdiella chrysoura	Menidia beryllina
Brevoortia tyrannus	Microgobius thalisinnus
Cynoscion regalis	Micropogonias undulatus
Dorosoma cepedianum	Morone americana
Fundulus heteroclitus	Morone saxatilis
Fundulus majalis	Opsanus tau
Gobiosoma bosci	Peprilus alepodotus
Ictalurus catus	Symphurus plagiusa
	Trinectes maculatus
	Total species = 21

GOODWIN ISLAND: (16 - 30 C), (15 - 24 p.p.t.)

Anchoa hepsetus	Micropogonias undulatus
Anchoa mitchilli	Mugil cephalus
Bairdiella chrysoura	Mugil curema
Centropristis striata	Mycteroperca microlepis

Table 20 (Continued)

Chasmodes bosquianus	Opsanus tau
Chilomycterus schoepfi	Paralichthys dentatus
Cynoscion nebulosus	Pomotomus saltatrix
Cynoscion regalis	Rachycentron canadum
Cyprinodon variegatus	Sciaenops ocellatus
Fundulus heteroclitus	Scomberomorus maculatus
Fundulus majalis	Sphoeroides maculatus
Gambusia affinis	Sphyraena guachancho
Gobiesox strumosus	Strongylura marina
Gobionellus boleosoma	Symphurus plagiusa
Gobiosoma bosci	Syngnathus floridae
Hippocampus erectus	Syngnathus fuscus
Hyporhamphus unifasciatus	Syngnathus louisianae
Hypsoblennius hentzi	Synodus foetens
Leiostomus xanthurus	Tautoga onitis
Lutjanus griseus	Trachinotus carolinus
Menidia menidia	Trinectes maculatus
Menticirrhus americana	Total Species = 43
Microgobius thalisinnus	

SITE LOCATION:

HOG ISLAND: (17 - 28 C), (28 - 33 p.p.t.)

Anchoa hepsetus	Menidia menidia
Anchoa mitchilli	Micropogonias undulatus

Table 20 (continued)

Baidiella chrysoura	Monocanthus hispidus
Centropristis striata	Mugil cephalus
Cynoscion regalis	Mugil curema
Cyprinodon variegatus	Mycteroperca microlepis
Diplodus holbrooki	Opsanus tau
Fundulus heteroclitus	Paralichthys dentaus
Fundulus majalis	Prionotus carolinus
Gerreidae	Prionotus evolans
Gobionellus boleosoma	Sphoeroides maculatus
Gobiosoma bosci	Stenotomus chrysops
Gobiosoma ginsburgi	Strongylura marina
Hypsoblennius hentzi	Synodus foetens
Leiostomus xanthurus	Tautoga onitis
Lutjanus griseus	Trinectes maculatus
	Total species = 32

WACHAPREAGUE (15 - 30 C), (26 - 29 p.p.t.)

Anchoa hepsetus	Microgobius thalisinnus
Anchoa mitchilli	Micropogonias undulatus
Bairdiella chrysoura	Monocanthus hispidus
Centropristis striata	Monocanthus setifer
Chaetodon ocellatus	Mugil cephalus
Conger oceanicus	Mugil curema
Cynoscion regalis	Mustelis canis
Etropus sp.	Opsanus tau

Table 20 (Continued)

Fundulus heteroclitus	Paralichthys dentatus
Fundulus majalis	Pomotomus saltatrix
Gerreidae	Sphoeroides maculatus
Gobiesox strumosus	Stenotomus chrysops
Gobiosoma bosci	Strongylura marina
Hippocampus erectus	Symphurus plagiusa
Hypsoblennius hentzi	Syngnathus fuscus
Leiostomus xanthurus	Synodus foetens
Lutjanus griseus	Tautoga onitis
Menidia menidia	Trinectes maculatus
	Total species = 36

CAPE CHARLES AND NANDUA CREEK: (bayside Eastern Shore, Va.)

(16 - 29 C), (17 -23 p.p.t.)

Astroscopus guttatus	Menidia menidia
Anchoa hepsetus	Microgobius thalisinnus
Anchoa mitchilli	Micropogonias undulatus
Bairdiella chrysoura	Mugil cephalus
Centropristis striata	Mycteroperca microlepis
Chaetodipterus faber	Opsanus tau
Chasmodes bosquianus	Orthopristis chrysoptera
Chilomycterus schoepfi	Paralichthys dentatus
Cynoscion nebulosus	Peprilus alepidotus
Cynoscion regalis	Pogonias cromis
Cyprinodon variegatus	Pomotomus saltatrix

Table 20 (continued)

Diplodus holbrooki	Prionotus carolinus
Etropus crassotus	Sciaenops ocellatus
Fistularia tabacaria	Scopthalmus aquosus
Fundulus heteroclitus	Sphoeroides maculatus
Fundulus majalis	Stenotomus chrysops
Gambusia affinis	Strongylura marina
Gerreidae	Syngnathus floridae
Gobiesox strumosus	Syngnathus fuscus
Gobiosoma bosci	Syngnathus louisianae
Hypsoblennius hentzi	Synodus foetens
Leiostomus xanthurus	Tautoga onitis
Lutjanus griseus	Trinectes maculatus
	Total species = 46

TABLE 21. Cumulative checklist of all fishes collected at all sites from June 1989 through m October 1991.

Anchoa hepsetus	Micropogonias undulatus
Anchoa mitchilli	Monocanthus hispidus
Anguilla rostrata	Monocanthus setifer
Astroscopus guttatus	Morone americana
Bairdiella chrysoura	Morone saxatilis
Brevoortia tyrannus	Mugil cephalus
Centropristis striata	Mugil curema
Chaetodipterus faber	Mustelis canis
Chaetodon ocellatus	Mycteroperca microlepis
Chasmodes bosquianus	Opsanus tau
Chilomycterus schoepfi	Orthopristis chrysoptera
Conger oceanicus	Paralichthys dentatus
Cynoscion nebulosus	Peprilus alepidotus
Cynoscion regalis	Pogonias cromis
Cyprinodon variegatus	Pomotomus saltatrix
Diplodus holbrooki	Prionotus carolinus
Dorosoma cepedianum	Prionotus evolans
Etropus crassotus	Sciaenops ocellatus
Fistularia tabacaria	Scomberomorus maculatus
Fundulus heteroclitus	Scopthalmus aquosus
Fundulus majalis	Sphoeroides maculatus
Gambusia affinis	Sphyraena guachancho

Gerreidae

Gobiesox strumosus

Gobionellus boleosoma

Gobiosoma bosci

Gobiosoma ginsburgi

Hippocampus erectus

Hyporhampus unifasciatus

Hypsoblennius hentzi

Ictalurus catus

Leiostomus xanthurus

Lutjanus griseus

Menidia menidia

Menticirrhus americana

Microgobius thalasinnus

Stenotomus chrysops

Strongylura marina

Symphurus plagiusa

Syngnathus floridae

Syngnathus fuscus

Syngnathus louisianae

Synodus foetens

Tautoga onitis

Trachinotus carolinus

Trinectes maculatus

Total species = 70

Table 22. Location, date of capture, salinity and lengths of young of the black drum collected from June, 1989 through October, 1991.

Location	Date	TL (mm)	SL (mm)
Nandua	30 Sept. 90	207	168
Nandua	30 Sept. 90	194	155
Nandua	30 Sept. 90	185	150
Nandua	9 Oct. 90	179	141
Nandua	9 Oct. 90	188	150
Nandua	9 Oct. 90	203	163
York R.	13 Feb. 91	175	138
York R.	13 Feb. 91	180	141
Assawoman	22 Sept. 91	208	167
Assawoman	22 Sept. 91	201	159
Assawoman	22 Sept. 91	223	178
Assawoman	1 Oct. 91	215	173
Poquoson	27 Oct. 91	242	194

DISCUSSION

The habitats sampled from 1989 through 1991 represented all of the reported habitats in which juvenile black drum have historically been collected from Delaware Bay to the Gulf of Mexico (see Frisbie, 1962 and Peters and McMichael, 1990 for review). Additionally, many of the communities we sampled had the same species assemblage described to co-occur with juvenile black drum (Richards and Castagna, 1972; McGovern, 1986; Daniel, 1988). The areas in which the few specimens collected were found, were shallow, hard to reach tidal creeks characterized by having non-descript, extremely muddy bottoms.

Rotenone sampling permits the collection of rare or cryptic fish species that are typically unavailable to standard trawl collections. Cowan and Birdsong (1985), sampled deeper channels and creeks on Virginia's eastern shore at three sites near our study area and identified 28 species of fishes of which black drum were not included. Although we did not collect any young of the year black drum in seaside rotenone samples, we did identify 44 species of fishes, 16 more than the number reported using standard trawls. Therefore, we feel that our sampling design was appropriate for collecting these fish, however, their rarity precludes their capture.

Although the rotenone sampling strategy failed to locate the juvenile nursery habitat of black drum, the effort did result in data describing the nursery habitat of other commercially and recreationally important fishes. Red drum, Sciaenops ocellatus, spotted seatrout, Cynoscion nebulosus, summer flounder, Paralichthys dentatus and tautog, Tautoga onitis, were all collected in large numbers. Additionally, we discovered a previously undetected nursery for gag, Mycteroperca microlepis, in the shallow grass beds of the lower Chesapeake Bay.

Frisbie (1961) documented the historical records of the occurrence of juveniles within Chesapeake Bay and commented on their rarity. Our sparse data appear to confirm Frisbie's (1961) hypothesis that young of the year black drum in Chesapeake Bay are uncommon.

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